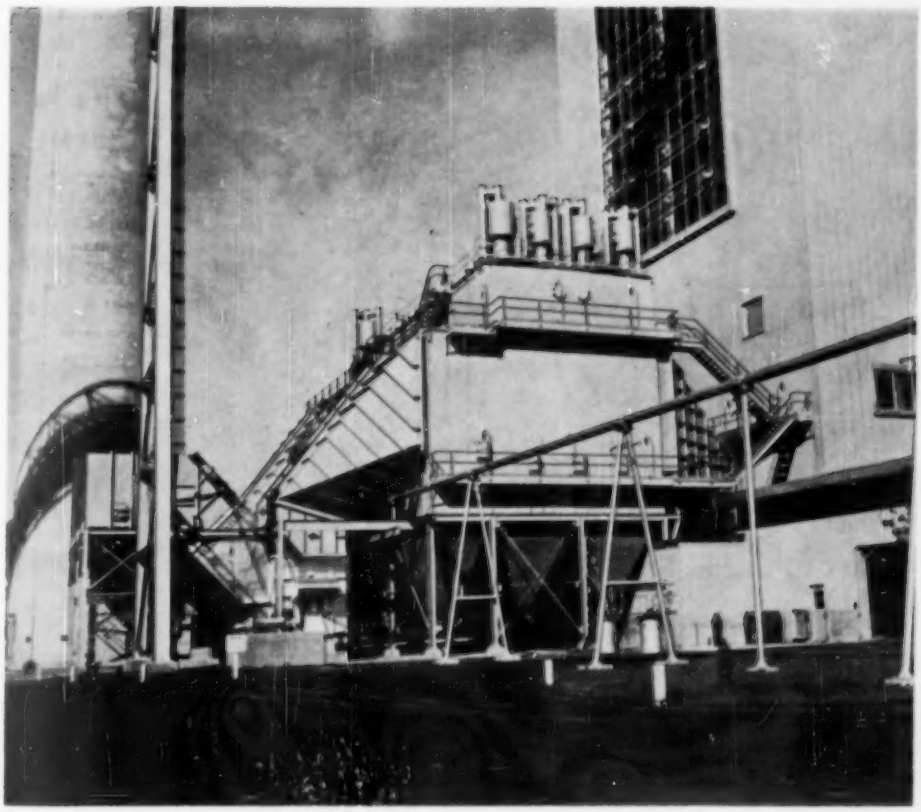
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



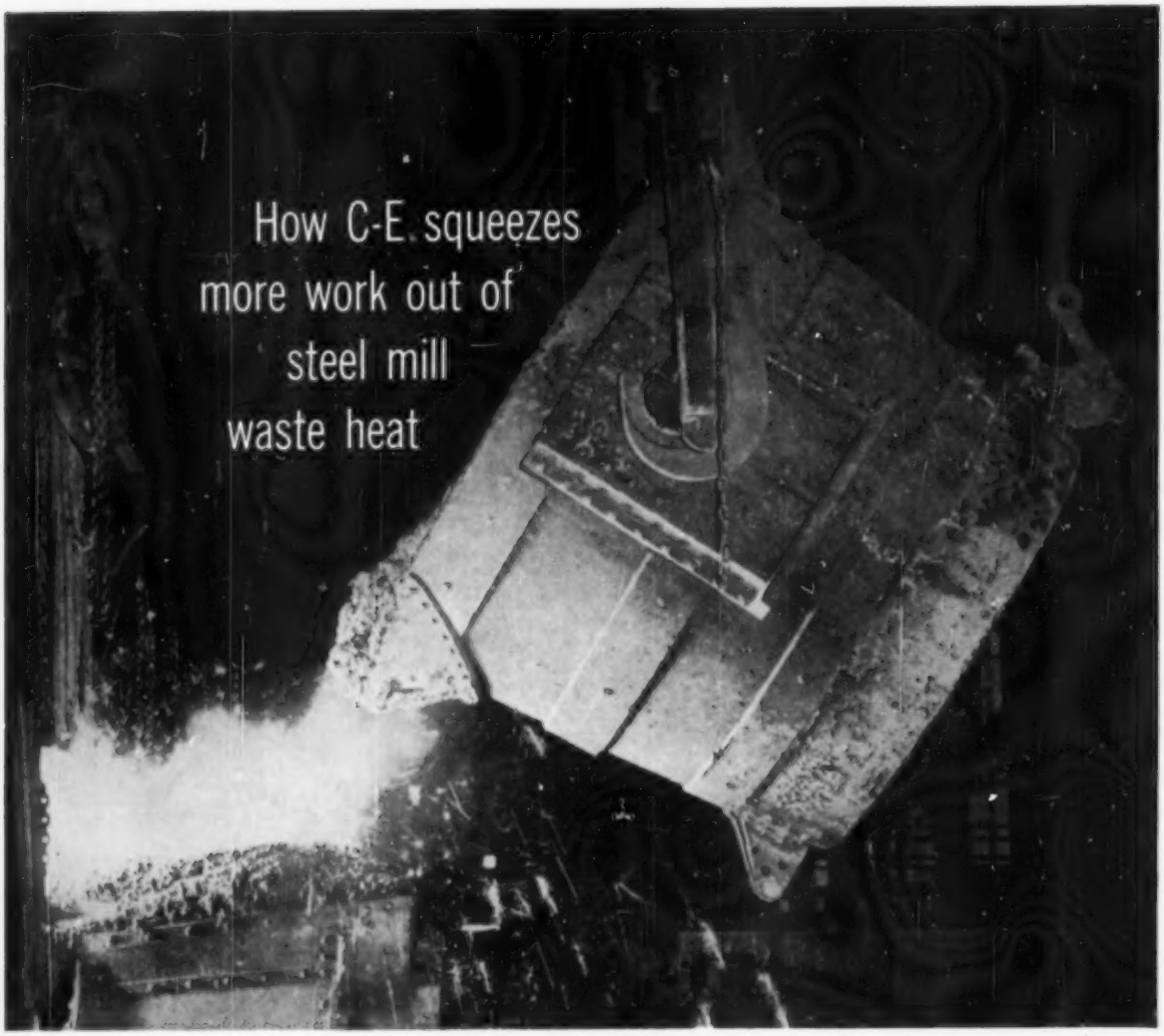
June 1961

Detecting Power Plant Service Failures

A New Look at Multiburner Scanning

Power Plant Clinic

Economics of a Combined Gas Turbine—Steam Cycle



Heat energy released in open hearth furnaces helps make more than 80 per cent of America's steel. In the process, much unused heat is discharged in the form of very hot gas from the open hearth exhaust.

Many kinds of waste heat boilers have been applied to the outlets of open hearths but their primary function has not been the efficient use of this excess heat energy. Rather, it has been their purpose to reduce the exhaust temperature so that the gas could be effectively cleaned in dust collectors prior to its discharge to atmosphere.

Combustion Engineering, experienced in the use of all kinds of marginal fuels and waste heat, and realizing the potential worth of open hearth gas as a power source, designed its Waste Heat Controlled Circulation Boiler–a truly *efficient* unit which makes *maximum* use of the tremendous energy in this gas.

Utilizing C-E's Controlled Circulation principle, this boiler will produce greater quantities of steam from a given volume of gas–and at more efficient working pressures and temperatures. It will handle this highly corrosive exhaust routinely, and with minimum maintenance.

It can be tailored to fit difficult space conditions. In short, it is a dependable and efficient source of low cost power which, in the process of doing more work, effectively cools the gas so that it may be cleaned.

Squeezing more work out of waste is a finely developed art at C-E. No matter its source, Combustion believes there is no such thing as *waste* heat–only *wasted* heat.

A C-E Controlled Circulation Waste Heat Boiler, Type WCC, being shipped to a major midwestern steel mill. One of a number installed at this mill, it utilizes the heat energy in open hearth exhaust gas to provide dependable, low cost steam power.

C-310

COMBUSTION ENGINEERING

GENERAL OFFICES: Windsor, Conn.
NEW YORK OFFICES: 200 Madison Avenue, New York 16

All types of Steam Generating, Fuel Burning and related equipment; Nuclear Reactors; Paper Mill equipment; Pulverizers; Flash Drying Systems; Pressure Vessels; Soil Pipe

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 32 number 12 **June 1961**

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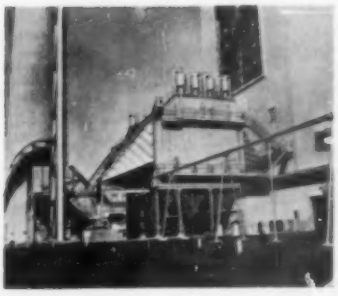
COVER PHOTO

The compact effect of close design is illustrated in this recent dust collector installation



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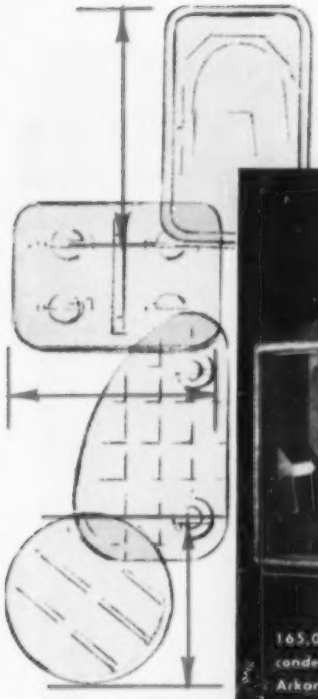
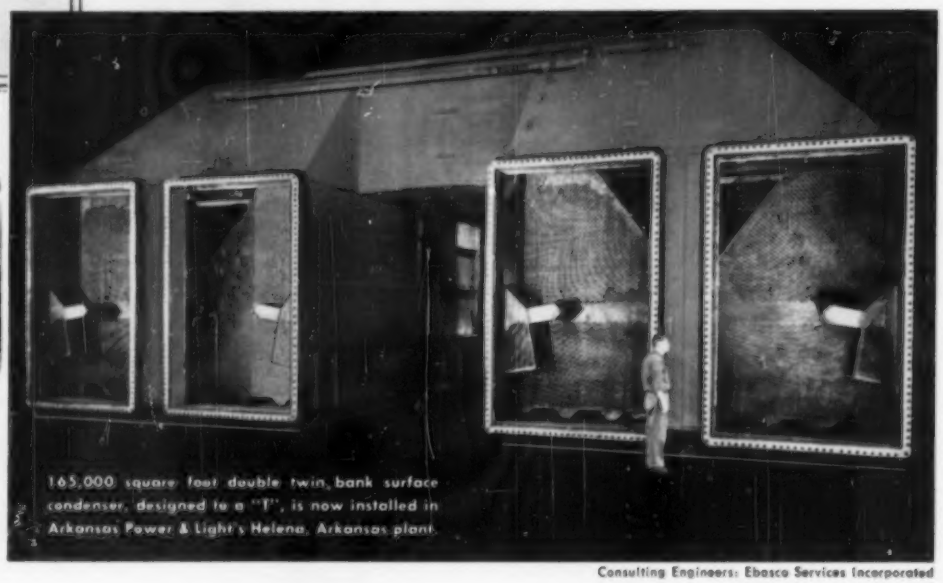


YUBA CONDENSERS
ANY SIZE . . . ANY ARRANGEMENT



165,000 square feet double twin-bank surface condenser, designed to a "T", is now installed in Arkansas Power & Light's Helena, Arkansas plant.

Consulting Engineers: Ebasco Services Incorporated

MOST VERSATILE TUBE BANK LAYOUT IN THE INDUSTRY

YUBA SURFACE CONDENSER DESIGN . . . most flexible . . . any size . . . any arrangement. Through design advances such as those incorporated in the unit above, Yuba illustrates the concepts you can expect from years of engineering leadership in the power industry.

Yuba's twin-bank tube layout, seen here in a two shell "T" type installation, promotes unobstructed, equally distributed flow. Through Yuba's patented design, the condensate can be deaerated with oxygen content guaranteed to be less than 0.005 cc per liter.

As a design extra, Yuba staggers the tube support plates – reducing harmonics – eliminating vibration. These are some of the reasons why Yuba surface condensers of all sizes have been installed in plants throughout the world. You'll want to know more about the most versatile tube bank layout in the industry – contact Yuba today.

Other Yuba products for steam power plants include feedwater heaters, evaporators, expansion joints, cranes, tanks, structural steel erection, and scores of other items.

YUBA

specialists in power plant equipment

YUBA HEAT TRANSFER CORPORATION
Tulsa, Oklahoma
Plants in Tulsa and Honesdale, Pa.

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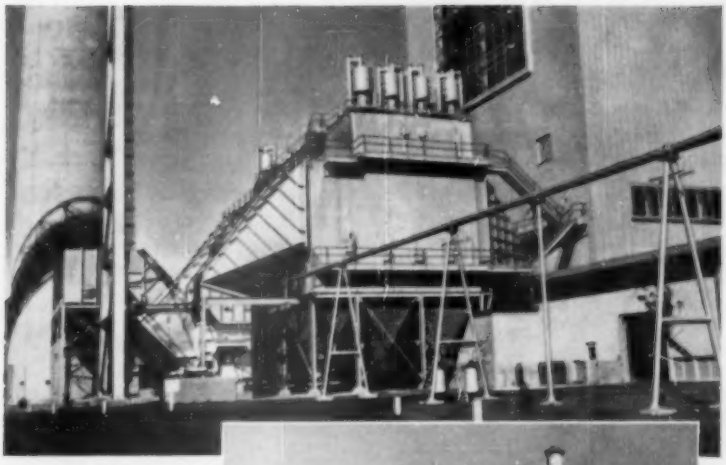

Research-Cottrell precipitator at a 150,000 KW generating station cleans over half a million cubic feet of gas per minute with 99% collection efficiency.

Con Edison's 350,000 KW generating station at Arthur Kill, Staten Island, has Research-Cottrell precipitators guaranteed to collect 99% of the fly ash from 1,400,000 cubic feet per minute of combustion gases.

Why These Plants Specify 99% Collection Efficiency

Industry's concerted efforts to solve the *air pollution* problem has resulted in an increased demand for 99% collection efficiency guarantees. Only through a continuing program of product improvement has Research-Cottrell made these 99% guarantees economically feasible. Efficient voltage application; specific control of electrical sections; opzel collecting plates; automatically controlled, fully adjustable electrode rapping for optimum operation; accurate internal baffling; proper gas flow patterns through three-dimensional model studies—these are a few of the reasons why Research-Cottrell has been able to increase collection efficiencies without increasing the size of the precipitator.

Research-Cottrell Extra Premium Experience and Know-How

Past performance and reliability are the two major barometers of experience and know-how.

These are the factors which have inspired confidence in Research-Cottrell products as exemplified in the most recent independent central station surveys made by Power and Electrical World magazines.

1960 SURVEYS of Typical Power Stations by both POWER and ELECTRICAL WORLD Magazines

	Research-Cottrell Equipment	
	Power	Electrical World
Percentage of Total Installations In Survey	36%	39%
Percentage of Total Precipitators In Survey	39%	35%
Percentage of Total Gas Cleaning Capacity In Survey	45%	42%

These surveys covered 47 modern central stations including over 75 electrostatic precipitators for air pollution control. In each survey, there were more Research-Cottrell installations reported than for any other of the half dozen manufacturers in the field.

Make sure you receive the "extra premium" which goes with every Research-Cottrell product—experience and know-how.

Research-Cottrell Personnel are capable of handling any problem in the field of gas cleaning and will gladly assist you with your application.

For more information on Research-Cottrell's program of product improvement, contact our local representative or write to the home office.

Research-Cottrell

COTTRELL®

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RC288

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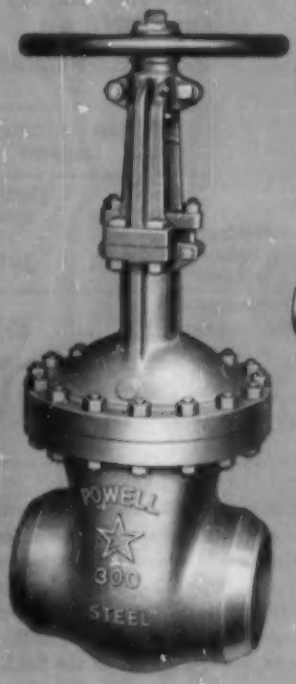
Performance proves it, year after year—you can count on Powell Valves to help you solve the toughest flow control problems of temperature and pressure found in power plants today.

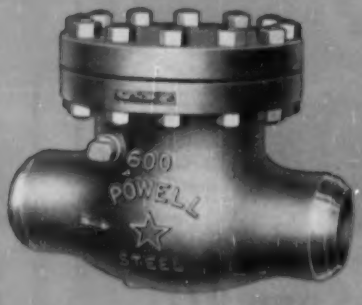
This truly dependable performance results from many things—among them Powell's engineering know-how, accumulated during 115 years of valve manufacture, and the consistent use of quality materials, quality controlled.

Then, too, you can count on getting the Powell Valve you need, when you need it. That's because Powell maintains a network of distributors backed up by factory inventories, warehoused "ready to go."

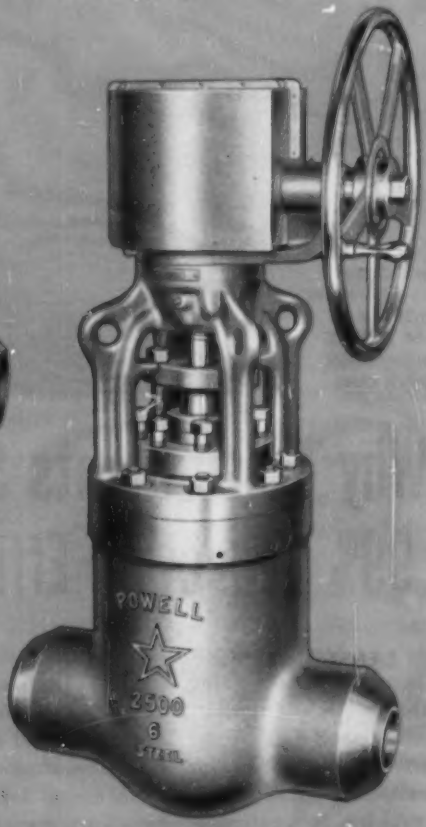
Get the full story from your nearby Powell Valve Distributor, or write us direct . . . The Wm. Powell Company, Cincinnati 22, Ohio.



300-pound Steel Gate Valve—Fig. 3003 WE. Bolted flanged yoke-bonnet. Outside screw rising stem. Interchangeable solid or split wedges, renewable seats. Sizes, 1" through 30".



600-pound Steel Horizontal Swing Check Valve—Fig. 6061 WE. Bolted cap, renewable seat and disc. Has full flow area when valve is fully open.



2500-pound Steel Pressure Seal Gate Valve—Fig. 125003 WE. Enclosed bevel gears facilitate operation. Valves can also be supplied with spur gearing or motor operators for remote control.

115th year of manufacturing industrial valves for the free world

POWELL STEEL VALVES

THE WM. POWELL COMPANY CINCINNATI 22, OHIO

Avon Lake No. 8 Demands Ultra-High Purity Water . . . and

NALCITE® ION EXCHANGE RESINS DO THE JOB

Cleveland Electric Illuminating Company's Makeup and Condensate Demineralizers Supply Mineral Free Water for the Avon Lake No. 8 Supercritical Steam Generator

It takes a lot of 1100° F steam to run the big, 250 MW turbogenerator at the Cleveland Electric Illuminating Company's Avon Lake plant. Because this steam is generated at a supercritical pressure of 3500 psia, water entering the steam generator *must* be pure—pure enough to meet requirements of a stringency unheard of only a few years ago.

PURE WATER ESSENTIAL FOR SUPERCRITICAL STEAM

Supercritical pressure steam at Avon Lake is generated at a 1,715,000 lb/hr rate in a monotube, or "once-through" boiler-superheater, which is, in effect, a series of heat exchanger tubes. Steam generated above critical pressure of 3205 psig does not form bubbles and separate from water (its density is the same as the water in the boiler). There is no opportunity for concentration and separation of impurities by blowdown. Therefore, water from which supercritical steam is produced must be free of impurities and suspended solids which would otherwise form deposits in the steam generator and turbine.

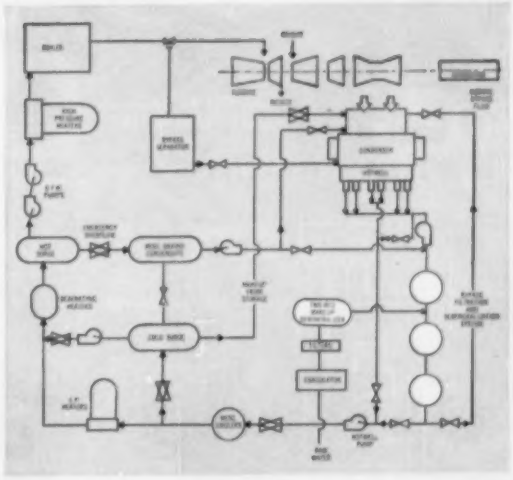
Specifications for the Avon Lake generator call for a maximum of 20 ppb silica, 20 ppb iron, and 10 ppb copper, at the economizer inlet.

CONDENSATE BYPASS DEMINERALIZERS KEEP WATER PURE

Condenser leakage (or "weepage"), corrosion products, auxiliary drains, and makeup water are all sources of contamination—contamination that can cause real trouble in the boiler and turbine. This contamination is controlled in the Avon No. 8 system by three mixed bed demineralizers on the condensate loop. Ionized materials are removed from the steam generator feedwater by three ion exchange beds, two of which contain Nalcite® HCR® and SBR-P©. Suspended matter is removed by pre-coat type filters. The demineralization equipment is generously sized, to provide "dynamic storage" of boiler water, and is capable of handling 100 per cent condensate flow at full turbine load.

EFFECTIVE DEMINERALIZATION FOR HIGH PURITY MAKEUP WATER

Makeup water from Lake Erie is coagulated and filtered, then passed through a standard



Simplified Flow Diagram of Avon Lake No. 8 Supercritical Steam Generating System

two-bed demineralizer containing Nalcite HCR® and Nalcite SBR-P© for removal of dissolved solids. Integral to the demineralizer is a vacuum deaerator for gas removal. The gas-free effluent of the demineralizer is further polished as it passes through the condensate bypass loop demineralizer.

PURITY, CAPACITY, AND DURABILITY

Industrial water demineralization calls for tough, uniform resin beads. Careful production of Nalcite resins holds the number of small beads to a minimum; thus pressure differentials across Nalcite resin beds are kept low. And, Nalcite resins are tough, durable, and long lasting under the roughest of conditions.

Nalcite ion exchange resins are available to help today's—and tomorrow's—engineers meet the demand for purer water at higher temperatures, pressures, and flow rates. For details on cation and anion exchangers offered by Nalco, write for Bulletins Z-12 and Z-13, free on request. For information on water conditioning with Nalcite resins, ask for Bulletin Z-5. If you need a fast, effective solution to a specific water treatment problem, Nalco experts are at your service. Call or write:

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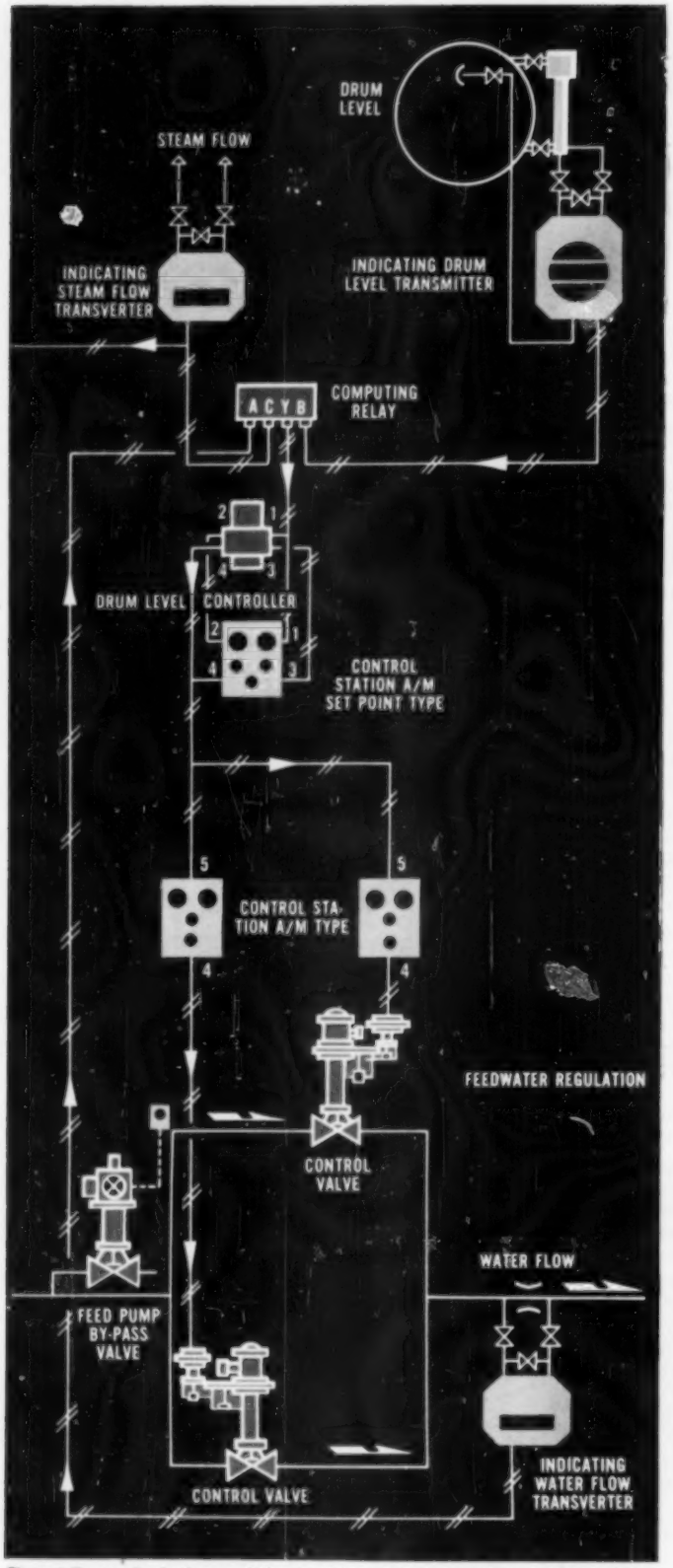
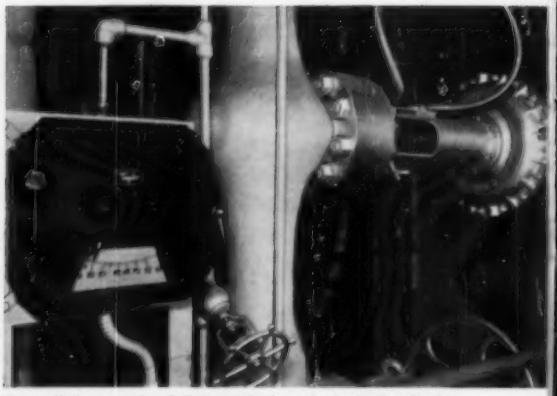
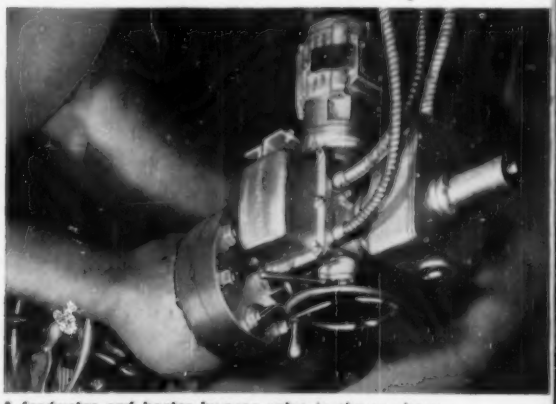


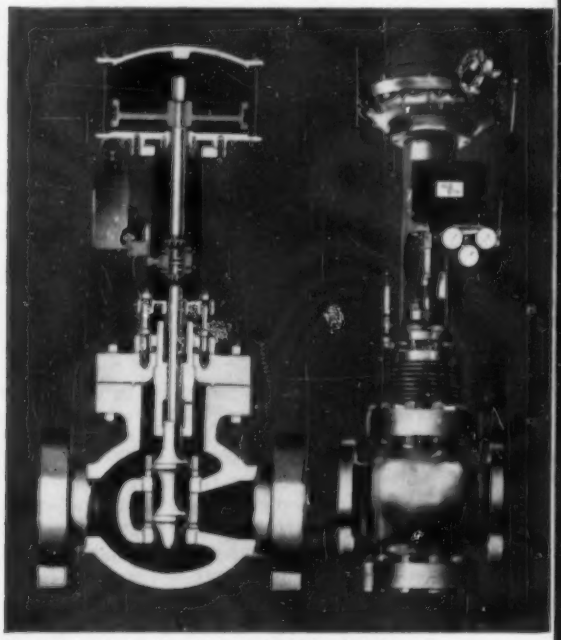
Three influence feedwater regulation is just part of a complete Copes-Vulcan boiler control system installed at a pace-setting utility station. Feed to boiler is modulated by steam flow, feedwater flow, and drum water level.



Copes-Vulcan recirculation control protects boiler feed pumps. When pump discharge falls below a certain level, a diaphragm-operated by-pass valve opens to assure sufficient flow to prevent overheating of the pump.



A feedwater and heater by-pass valve is shown above. Also, a Copes-Vulcan control valve is installed in each of the two main boiler feed lines. These valves handle pressure drops of over 2600 psig without difficulty.



Versatile control valves feature simplicity of design. Piston-type CV-P (left) is ideal for high-duty service. Diaphragm-type CV-D (right) is designed for remote control service. All Copes-Vulcan valves are tailored to the job.

COPES-VULCAN control valves make boiler feedwater systems accurate and trouble-free . . .

The big load changes of today's boilers put tremendous demands on the accuracy and dependability of feedwater and recirculation systems. Copes-Vulcan systems meet these demands with positive control, positive performance. ■ As long-time specialists in feedwater control, Copes-Vulcan has the experience and design know-how to custom-engineer control valves to rigid specifications. Regardless of high pressure drops, you get close control over full load range, without costly maintenance or replacement. ■ To the dynamic balance of the valves, Copes-Vulcan adds advanced instrumentation. The highly-responsive control system stabilizes water level regardless of changes in load or feed pressure. ■ Bulletin 1038 describes efficient boiler control at a key eastern power station. Write for your copy.
Copes-Vulcan Division, Erie 4, Pennsylvania.

Copes-Vulcan Division
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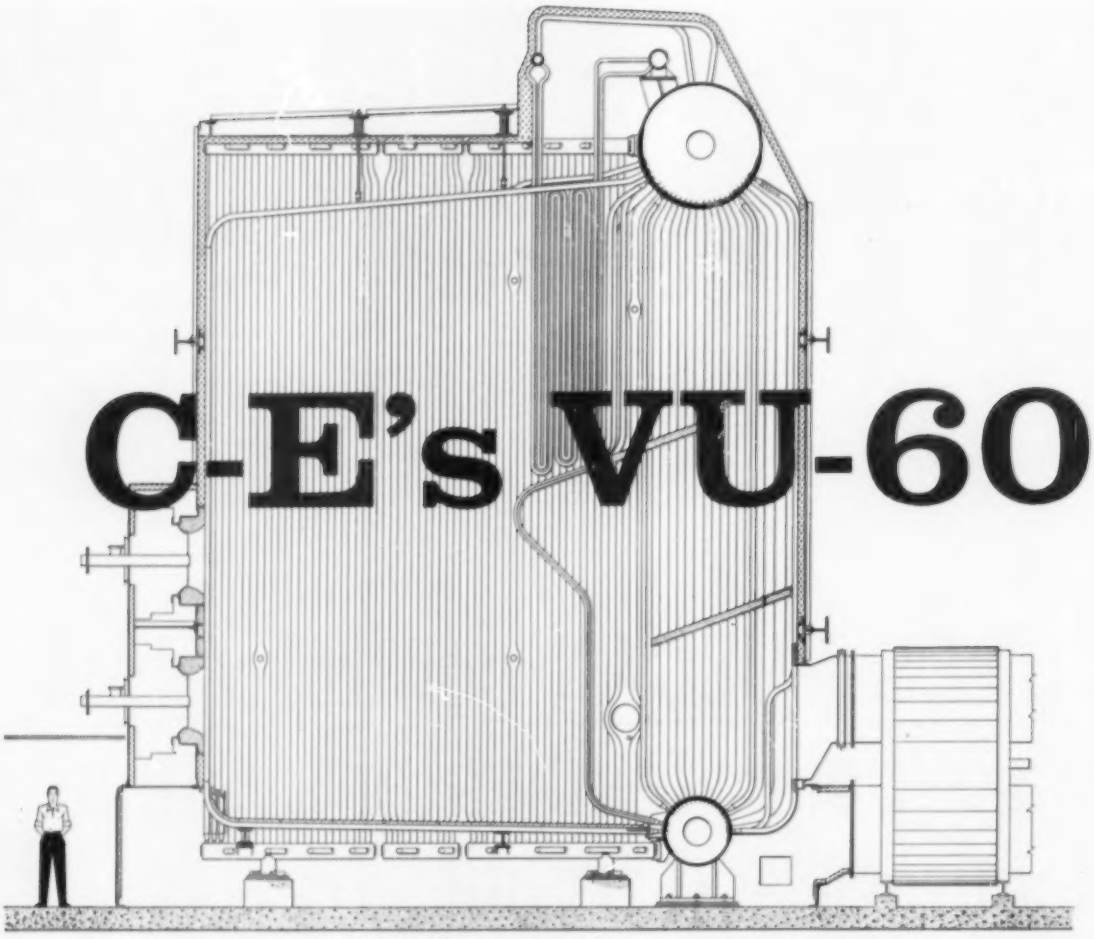
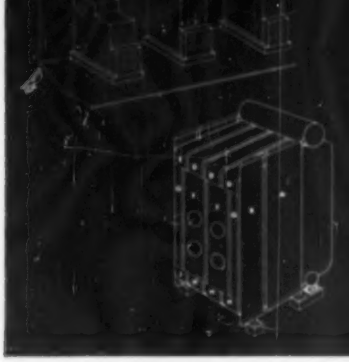
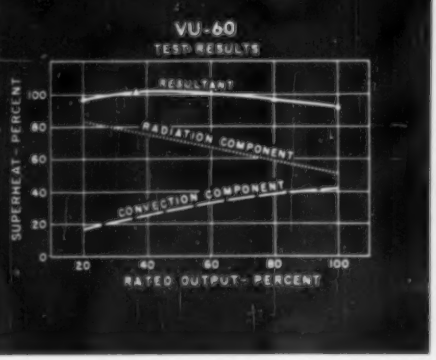
C-E's VU-60



SOME DESIGN HIGHLIGHTS OF THE VU-60





Modular increments allow assembly of custom designs from standardized components; boiler can be proportioned for best combustion, heat absorption, gas flow — even where space conditions are difficult.

Completely self-cased, the VU-60 is an all-welded pressure-tight envelope composed of modular panels of finned tubes; fewer field welds cut erection time.

Insulation and preformed lagging go directly over tube panels, thus reducing non-working weight per pound of steam generated.

Characteristic of Combustion's VU-60. This superheater curve indicates a temperature stability throughout entire load range.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER

GIVES YOU A CUSTOM-DESIGNED BOILER BASED ON STANDARDIZED MODULAR COMPONENTS

Because of its unique modular concept, C-E's new VU-60 offers unusual flexibility and can be designed to meet unusual or difficult space conditions.

VU-60 SPECIFICATIONS

Capacities:	100,000 to 250,000 lb per hr
Design pressures:	250, 500, 750, 1040 psi
Steam temperatures:	to 900F
Fuels:	Oil and/or gas
Firing:	Horizontal (front wall) or tangential
Size increments:	Depth-twelve Width-eight Height-three
Steam drum sizes:	Four

The VU-60 is a completely self-cased boiler. Finned tubes, shop-welded into modular panels, make up the exterior walls of the unit. The fins joining the panels are field-welded to make a pressure-tight envelope. Insulation is applied directly over these walls and is covered by pre-formed, field-installed metal lagging. The need for bulky or heavy nonworking structural members is kept to a minimum.

The VU-60 can be designed to meet your most exacting steam needs. It is easy to install, economical and dependable in operation, completely accessible and functional. Why not get full information on how this new concept can fulfill your specialized requirements?

COMBUSTION ENGINEERING

General Offices: Windsor, Conn., New York Offices: 200 Madison Avenue, New York 16, N. Y.
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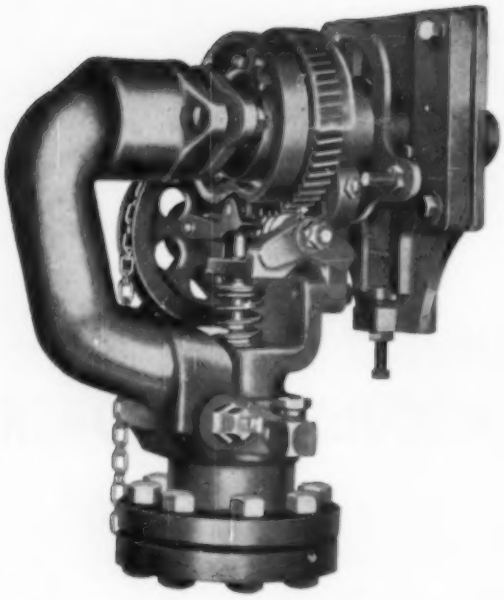
C-322

MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

Agencies

New York	Cleveland	Boston	Los Angeles	Charlotte	Salt Lake City	Washington, D.C.
Philadelphia	Detroit	Seattle	Cincinnati	Richmond	Houston	Atlanta
Chicago	Pittsburgh	St. Paul	Indianapolis	Denver	Kansas City	Tulsa

The BAYER COMPANY

4030 Chouteau Avenue, St. Louis 10, Missouri

YARWAY news briefs

from **Yarnall-Waring Company,** *Philadelphia 18, Pa.*

BRANCH OFFICES IN 19 UNITED STATES CITIES • SALES REPRESENTATIVES THROUGHOUT THE WORLD

HOW TO GET REMOTE LIQUID LEVEL READINGS YOU CAN DEPEND ON

• for boilers, feedwater heaters, deaerators, storage tanks, other vessels

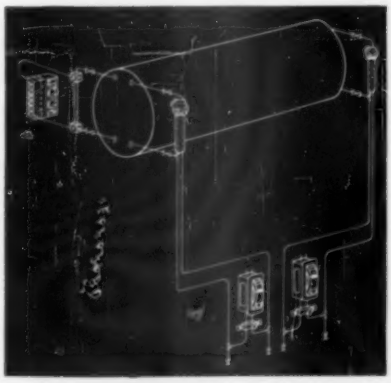
Dependability is the key to successful remote indication of liquid levels. To be *dependable*, indicating instruments must be *accurate* and *visible*. YARWAY REMOTE LIQUID LEVEL INDICATORS offer both these features—and a record of more than 16,000 successful installations in utilities, industrial plants, institutions and marine service.

ACCURATE—because the indicator is operated by the boiler water (or other liquid) itself. The varying head instantly actuates the operating mechanism, yet the pointer mechanism *is never under pressure.*

BRILLIANTLY VISIBLE — because the brightly-illuminated, wide-vision dial can be read at a glance from multiple vantage points, including any place in a 180° arc.

Through use of a Control Unit, additional remote horn or light signal alarms may be operated from a Yarway Indicator.

Get the full story on Yarway Indicators in Bulletin RI-1825—including 17 typical installation hook-ups. Write for your copy today.



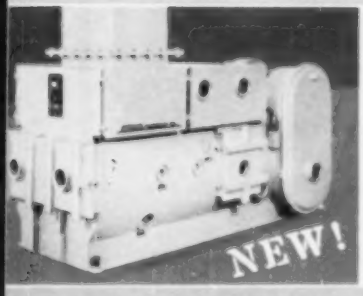
YARWAY INDICATORS ARE FULLY APPROVED AS PRIMARY INDICATING ELEMENTS UNDER BOILER CODE CASE #1155

Under A. S. M. E. Boiler Code Committee ruling in Case #1155, two independent remote level indicators of compensated manometric type may be used instead of one of two required gage glasses for boiler pressures 900 psi and above. When both indicators are in operation, the gage glass may be shut off but shall be maintained in serviceable condition.

Yarway Remote Liquid Level Indicators conform to and are widely used under this ruling.

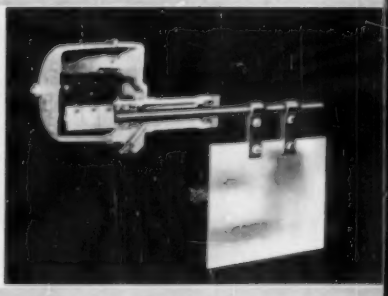
If you would like a copy of this Boiler Code ruling, just write and ask for Case #1155 reprint.

S-E-Co. QUALITY PRODUCTS



GRAVIMETRIC FEEDERS
Weigh and Feed

VOLUMETRIC FEEDERS
Feed Sticky Coals



STOPPAGE ALARMS
Two Types

S-E-Co. GRAVIMETRIC FEEDERS ALSO INDICATE COAL FLOW RATE AND TOTAL COAL

S-E-Co. Gravimetric Feeders for pulverizers or cyclone burners give reliable and useful indication of rate of coal flow and of total coal consumption.

The rate of coal flow through each feeder is determined by the speed of the head shaft. S-E-Co. Gravimetric Feeders discharge exactly 100 pounds of coal per turn of the head shaft, so the weight of coal per hour is directly proportional to RPM. The indicating instrument which is provided shows the coal flow rate directly in pounds per hour. A feed rate signal can also be supplied as required for recording instruments or for feedback into the control system.

Total coal flow is given by the number of revolutions of the feeder head shaft. The coal integrator is simply a counter driven by pulses taken from the head shaft. Absolute accuracy with no instrument drift is thus assured. The integrator reading times 100 is the total coal weight in pounds. The same pulse for every 100 pounds is ideally suited for entering coal flow information into data logging equipment. If preferred, pulses can be provided instead for any multiple or submultiple of 100 pounds.

S-E-Co. Gravimetric Feeders offer the instrumentation that helps attain the peak of perfection in plant operations. From indication of rate of coal flow in pounds per hour, exact balancing of fuel to each mill or cyclone is easily achieved. The instantaneous station heat rate can be determined quickly by a simple, *direct* procedure. Accuracy in the indication of total weight of coal burned means better records and hence better plant results, as well as proper maintenance scheduling. The advantages become even more pronounced with increasingly automatic control or with computer control.

One of the factors contributing to the precision of coal flow measurements with all S-E-Co. Feeders is their unusually high and non-varying volumetric efficiency. Regardless of whether your coal is wet and sticky, or dry and dusty, or frozen and full of lumps, the indication given of coal flow rate is consistent. With S-E-Co. Gravimetric Feeders, fluctuations in the coal density resulting from varying size consist, moisture, or compaction are eliminated.

For further comments on plant operation with S-E-Co. Gravimetric Feeders, *send your inquiry to*

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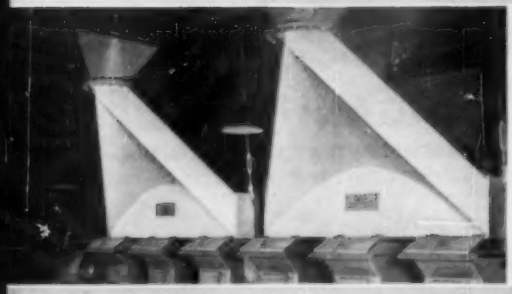
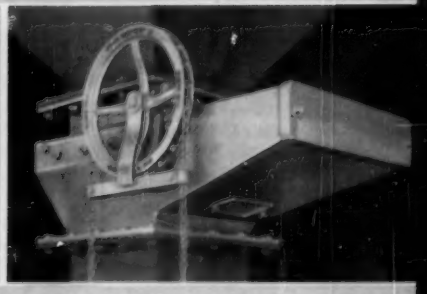
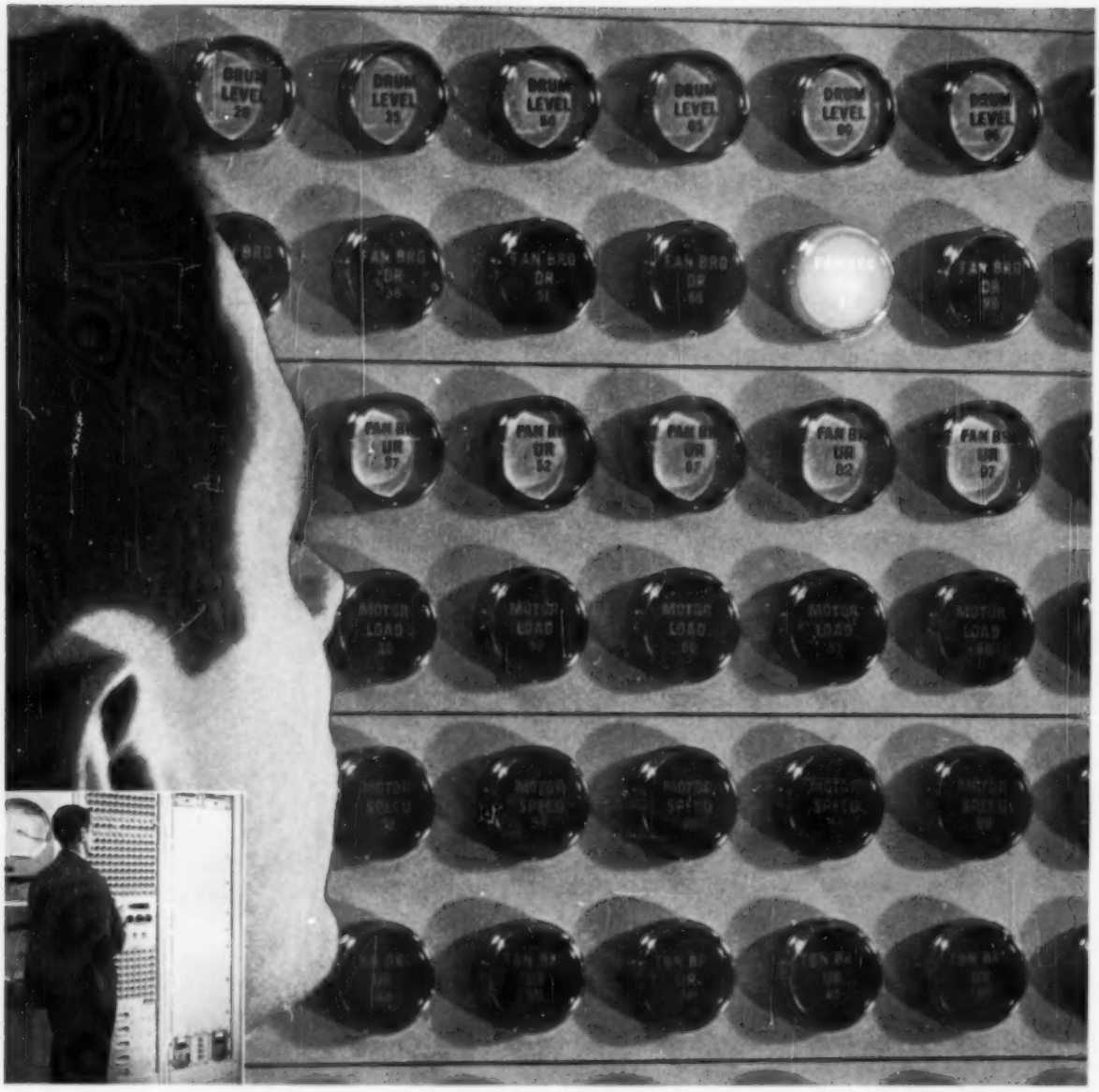


CONICAL NON-SEGREGATING
COAL DISTRIBUTORS

COAL SCALES
Two Basic Sizes



COAL VALVES
6" to 60" — Many Styles



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Designed to protect valuable plant equipment, the Hagan AIM makes it possible for one man to monitor pressures, temperatures, flows, levels, closures from several critical areas at the same time. AIM can be set for either high or low alarm points, or both.

Combining all alarm functions in one instrument, the AIM will monitor *any* input which can be represented by DC voltages as low as 10 millivolts full scale, with an accuracy of ± 0.1% full scale. Providing maximum information on minimum panel space, the readout and alarm panel for 200 alarm points will fit into a 19″ × 47¼″ panel area.

For more information about the low-cost Hagan AIM, write or phone the address below.

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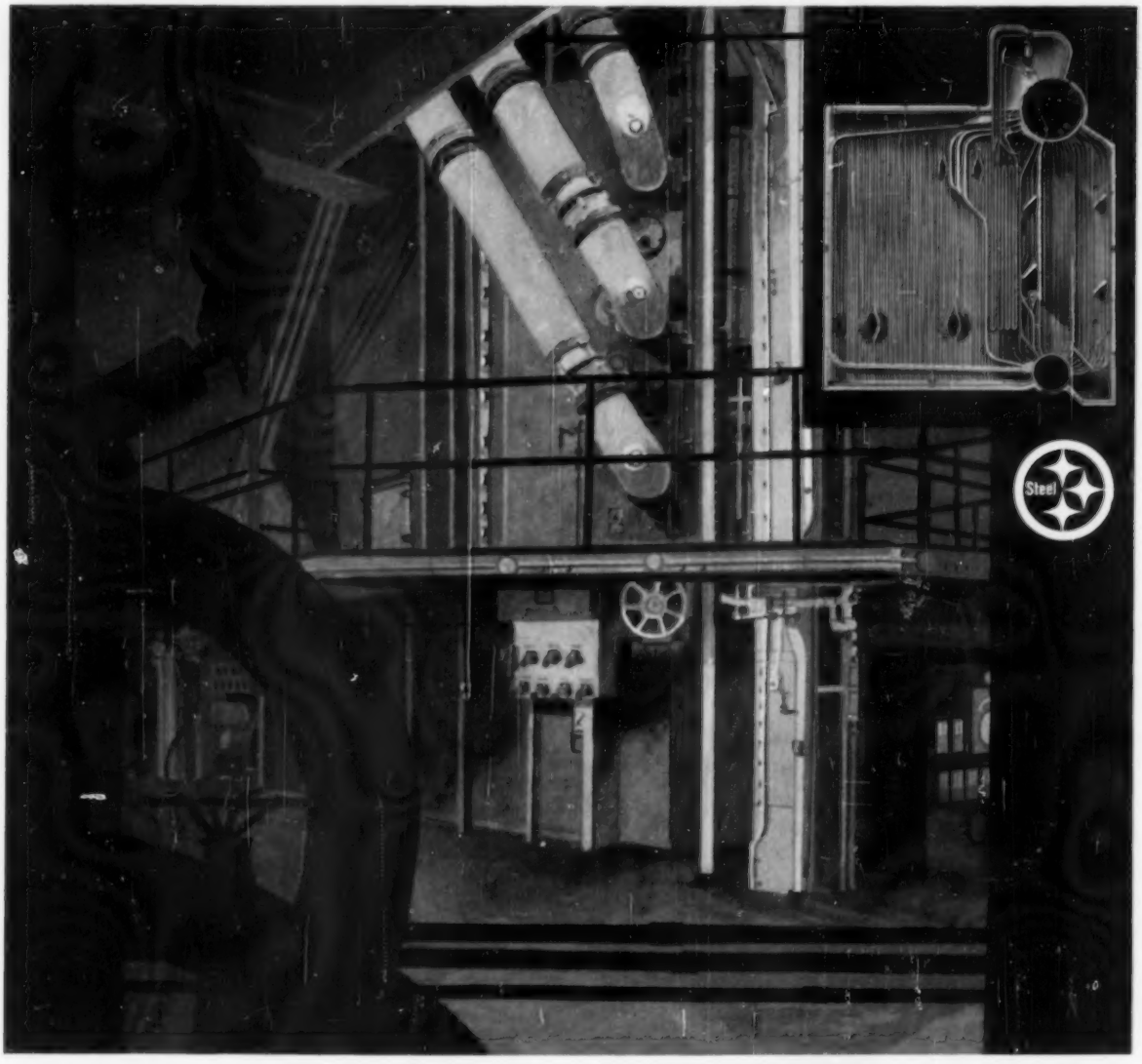

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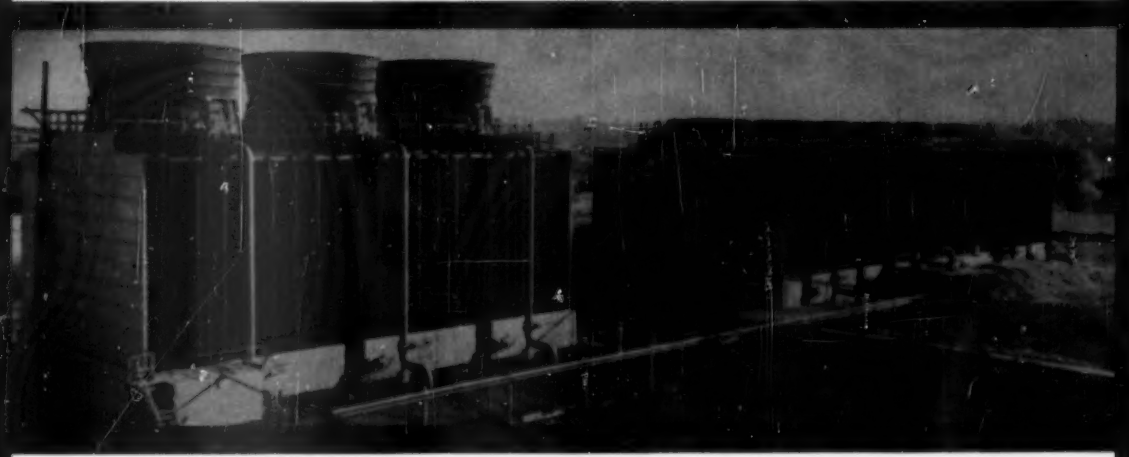

Cooling System No. 2 at Iowa Southern Utilities Company's Bridgeport Station circulates 19,000 gpm and includes this Tower. Inlet temperatures range from 83 to 90°F; outlet temperatures 70 to 75°F. To this System, Dearborn 860 with Endcor B was fed for comparative tests with System No. 1 in which prior treatment was continued. Corrosion testers installed in by-pass lines of the return water riser in each Tower gave comparative results—serious localized or pitting type corrosion at a rate averaging 10 to 12 mils per year in System No. 1; complete absence of pitting and a corrosion rate of only 1.2 mils in System No. 2 using 860 with Endcor B.

Endcor® proves its superiority in cooling water treatment

Whether it's Endcor A combined in polychromate formulations or Endcor B in non-toxic dimetallic polyphosphates, these organic additives—developed in Dearborn's research laboratories—continue to prove their superiority *in actual plant operation everywhere.*

For example, at Iowa Southern Utilities' modern 66,000 KW Bridgeport generating station (Eddyville, Iowa) Dearborn® 860 with Endcor B *completely eliminated* pitting and reduced the corrosion rate from 12 to 1.2 mils per year. It also produced a significant reduction in the reversion rate of polyphosphates as compared with the previous sodium hexametaphosphate and tannin treatment. Results: First, economy, since more polyphosphate is available per unit fed; second, improved performance, because of less insoluble phosphates to deposit in heat exchangers.

But there's more involved in Dearborn service than just product superiority. There's the important "plus" of Dearborn's water treatment experience—from source to re-use—dating back to 1887—longest in the field. There's its extensive research and analytical facilities... its Technical Centers in Chicago and Toronto, staffed with recognized experts to analyze and solve specific problems . . . to make certain that Dearborn products and equipment give top performance always.

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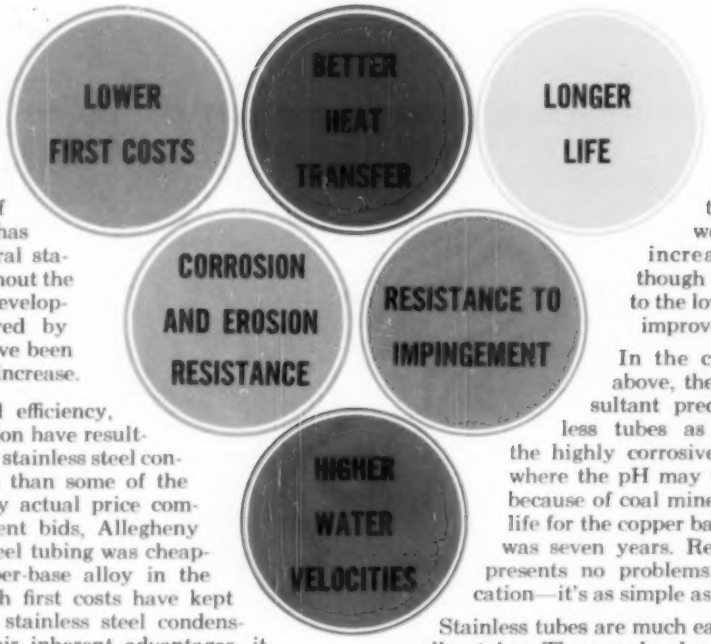
NEW DEVELOPMENTS IN ALLEGHENY STAINLESS STEEL CONDENSER TUBES MEAN



In the last three years, over 3 million feet of stainless steel tubing has been installed in central station condensers throughout the United States. New developments, many sponsored by Allegheny Ludlum, have been responsible for this increase.

Automation, improved efficiency, and increased production have resulted in lower prices. Now stainless steel condenser tubes cost less than some of the copper alloy tubes. By actual price comparisons on some recent bids, Allegheny Type 304 Stainless Steel tubing was cheaper than a usual copper-base alloy in the same diameter. If high first costs have kept you from considering stainless steel condenser tubing with all their inherent advantages, it will pay you to re-investigate.

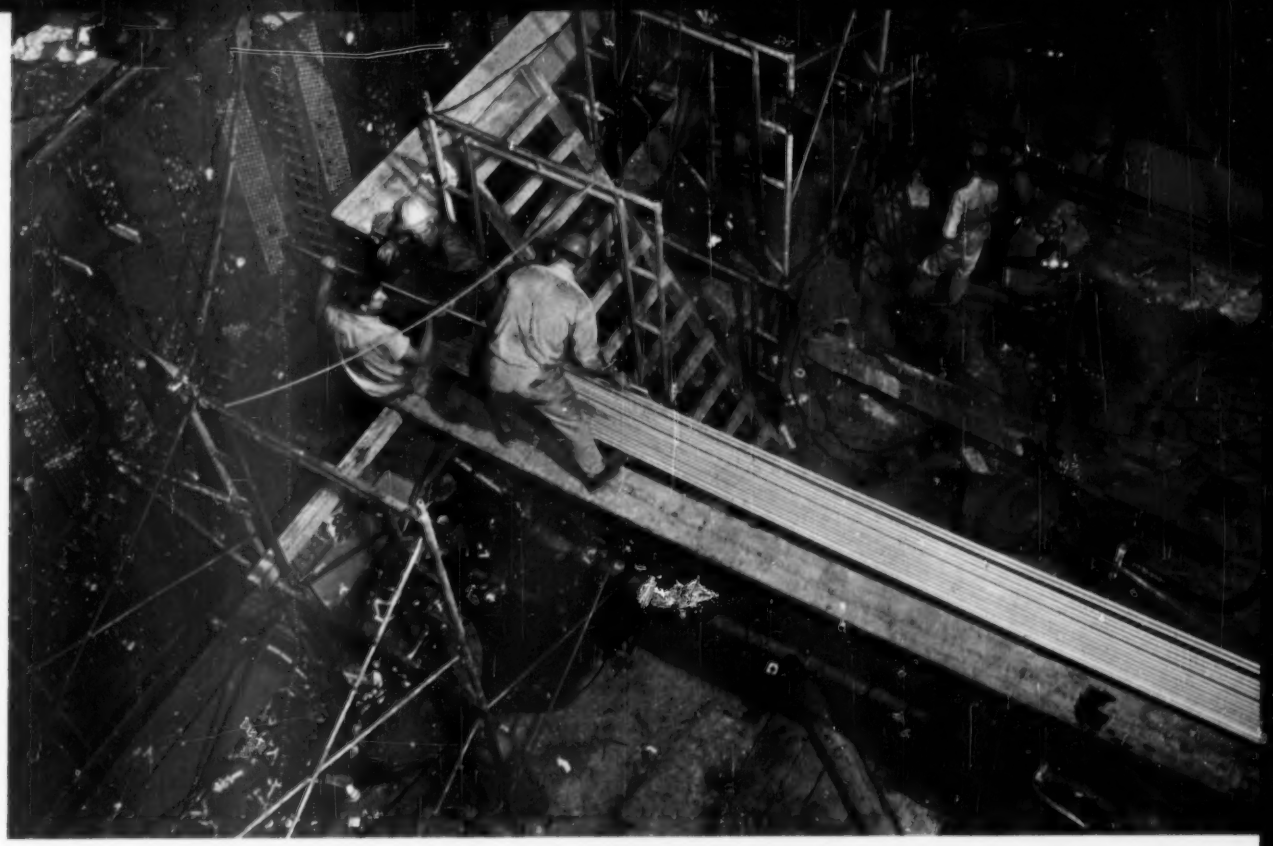
Increased operating data have shown that the in-use heat transfer rates on condenser tubes are much superior to the published data of a decade ago. Exhaustive tests made at a condenser completely re-tubed with Allegheny Type 304 Stainless Steel in May 1958 showed that the actual over-all heat rate on the turbine was improved over the 88-10-2 copper tubes previously used. Part of the answer is the thinner wall possible in the stainless tubing, 22-Bwg, compared with the 16-Bwg copper alloy tubing formerly used.

The superior strength of stainless allowed these thinner walls. In spite of the larger inside diameter, cooling water velocity through the tubes averaged ½ FPS more in stainless, although the pumping facilities were not changed. This increase in velocity, even though the ID is larger, is due to the lower flow resistance and improved interior cleanness.

In the condenser mentioned above, the utility and their consultant predict the life of stainless tubes as thirty years despite the highly corrosive river water involved where the pH may vary from three to six because of coal mine drainage. Previously, life for the copper base tubes formerly used was seven years. Re-tubing with stainless presents no problems, calls for no modification—it's as simple as re-tubing with copper.

Stainless tubes are much easier to clean than copper alloy tubes. They are harder and tougher. The mud and slime do not cling to the surface. With copper tubes, it was impossible to clean these condenser tubes without using oversize cleaning plugs which would have affected tube life. Practical cleanliness of copper tubing averages less than 60%. After re-tubing with Allegheny Stainless, one shot with nylon brushes restored cleanliness to the as-new condition.

Another major trend is the partial use of stainless tubes to resist excessive steam-side erosion. Many condensers are being specified or re-tubed with stainless tubes in the outer banks to resist blasting action or steam impingement. Generally, approximately 5% of the total tubes are specified stainless for the periphery. Even here, 22-Bwg stainless is usual where 18-Bwg or less is necessary in the copper alloys.



Retubing the air removal section of this condenser with Allegheny Stainless Tubes eliminated attack by the high ammonia content of the non-condensibles.

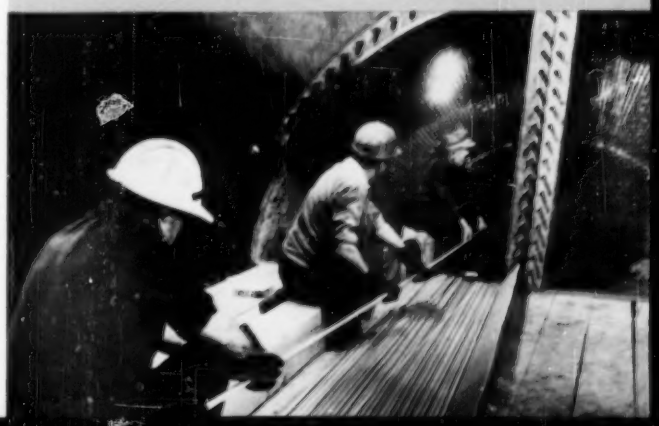
Another trend is the use of stainless in the air cooler or residual condenser section. Copper tubes tend to stress crack and fail because of the ammines used for water purification. Under these conditions, stainless tubes remain unaffected even under excessive build-up of ammonia in the non-condensibles.

On the horizons in heat transfer equipment design is an all stainless steel condenser that will result in an overall size reduction. With the higher strength and the less resistance to water flow of stainless tubes, water velocity through the tubes can be doubled. Erosion and corrosion can be virtually eliminated. Right now, several consulting firms are evaluating this latest development.

Stainless steel condenser tubing is welded from high quality stainless steel strip on automatic machinery. After fabrication, they are cold drawn to increase strength and improve finish. Stainless steel condenser tubes are guaranteed against preferential corrosion attack at the weld. They can be rolled or welded into the tube sheet with the same equipment and procedures as with copper alloys. At the tube sheet, stainless steel resists oxygen release. There are no galvanic problems.

The trend to stainless steel condenser tubes is growing by leaps and bounds. For more facts, details, and general information, contact the nearest Allegheny Ludlum representative or write: ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.***

No deterioration after 17 years of operating tests in river water made highly corrosive by coal mine drainage resulted in the selection of Type 304 Allegheny Stainless for the tubes in this condenser unit.



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Long-Life CR construction includes heavy-gauge reinforced steel plate housings and inlet boxes with air-tight access doors; heavy-duty self-aligning sleeve or water-cooled bearings; and shafts sized to run well below critical speed and ground to a close fit on the thrust bearing.

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For first-cost savings and continued low-cost performance on many severe services, there is no better buy than the 'Buffalo' Type CR Fan. Write for Bulletin FD-205.

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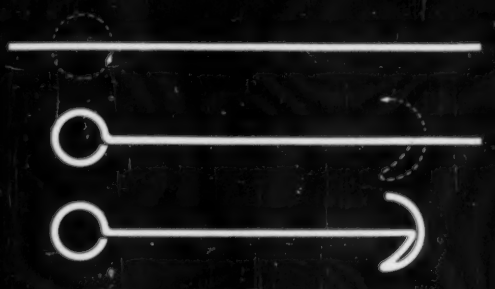
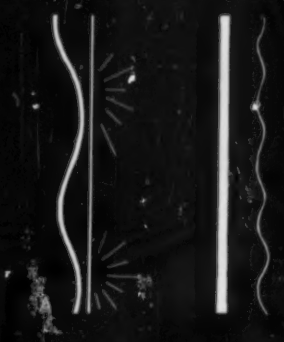
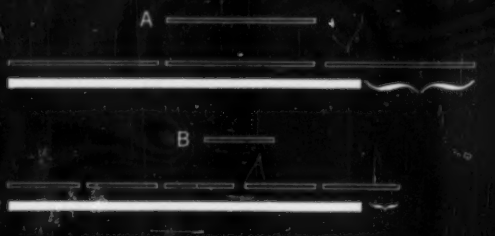
COLLECTING ELECTRODE DESIGN ANOTHER REASON FOR SUPERIOR PERFORMANCE OF BUELL PRECIPITATORS



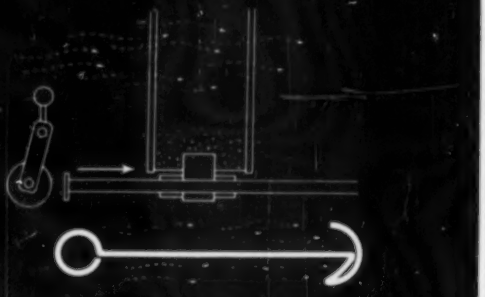
HEAVIEST CONSTRUCTION, ONE-PIECE FABRICATION Rolled, from a single piece, the structural design and thickness of the Buell collecting electrode provides the strength to retain proper shape and alignment in erection and operation.



EASE OF HANDLING AND INSTALLATION – Rugged sections can be installed without bending or distortion thereby eliminating the possibility of 'arc-overs' (A).



OPTIMUM FLEXIBILITY IN DESIGN OF PRECIPITATOR –Standard 16" width (B) allows increase in size of precipitator by smaller increments (not by 3 foot (A) or longer sections). Permits economical sizing of precipitator to specific requirements of efficiency and space.



POSITIVE "SHEARING ACTION" DESIGN – No reentrainment of dust in rapping. Each row of electrodes is rapped separately–in the direction of the gas flow–on a continuous cycle. Dust is sheared off, drops in an agglomerated mass, and pockets on electrodes minimize reehtrainment.

Add to this Buell's exclusive baffling system adjustable after installation for uniform distribution of gas flow, sealed insulators, rigid, 4-point suspension of emitting system, and high emittance, minimum maintenance Spiralectrodes and you have a combination that's hard to beat. You'll be glad you decided on Buell precipitators when you experience superior performance and minimum maintenance. Buell Engineering Company, Inc., Dept. 70-F, 123 William Street, New York 38, New York. Northern Blower Division, 6413 Barberton Avenue, Cleveland, Ohio. Electric Precipitators • Cyclones • Bag Collectors • Combination Systems • Fans • Classifiers

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GUEST EDITORIAL

Three Billion People

Walker L. Cisler

Today, more than at any time since the end of World War II, the international situation is tense and confused. Changes and pressures toward change are apparent in Europe, Asia, Oceania and in the Western Hemisphere. Behind many of these changes is the innovating force of technology, which is itself in a process of rapid development.

There are about three billion people on the planet, most of whom are struggling to attain a better existence.

Three billion people are struggling, often at cross purposes, to reap the material results of a technical age.

Three billion people are struggling for a better existence, but as yet perhaps no more than a fifth of them have achieved a significant degree of industrialization.

There are four major imbalances at the root of most of the tensions we see around us. These are unequal distribution of population, imbalance in the distribution of natural resources, the uneven distribution of fuels and a serious imbalance of the distribution of the means of production.

Added to these imbalances is the difficulty of initiating industrialization in a poor country. In the early stages, the initial cost far exceeds the immediate monetary gains. More ways must be found to help nations over this barrier.

Can these problems be solved? Will men allow themselves the time to work out sensible solutions?

As an engineer with some experience in international assistance, I can answer most affirmatively that the chances are very good indeed. I have seen men in the jungle, one generation removed from tribal life, doing skillful work with machines and performing exacting technical services in hospitals. Some men of this caliber—and there are many all over the world with abilities now going to waste—can be trained as scientists, engineers, teachers, doctors, managers of enterprise. With their help the great task of educating an entire population to the responsibilities of a modern society can then be hopefully undertaken.

We cannot buy friendship, but we can help people to help themselves through cultural and technical exchange programs. Part of the lesson others can learn from us is that economic progress is possible without paying the drastic price of surrendering freedom.

Unless those of us who are in a position to work for the improvement of international understanding do so, I hold little hope for an enduring peace. Fortunately, many are at work. Technical and cultural exchanges are going on and official discussions continue. The most dangerous time would be when we no longer spoke, no longer argued.

We must be patient in ways for which our common biological inheritance gives us little preparation. In a technological age, when great sources of energy can be released for good or for evil by pressing a few buttons, men must learn to control their emotions and to use their abilities to upgrade the resources of our planet for the common good. There is no other course worthy of human dignity.

Walker L. Cisler

President
THE DETROIT EDISON CO.

Detecting Service Failures in Power Plants*

By HELMUT THIELSCH†
Grinnell Company, Inc.

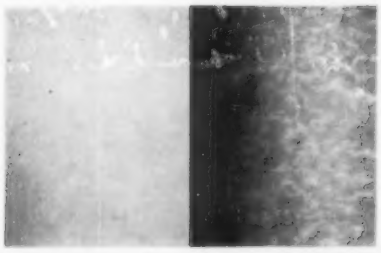
Fig. 2—Set-up for inspection of pipe weld joint with Iridium 192 radiation source

Part I. Techniques

The gradual, silent collapse of the pressure members of the typical steam-power cycle has defied the otherwise reliable shift-by-shift, watch engineer's visual appraisal of equipment performance. Here is a two-part roundup of the newer inspection techniques now being perfected and a series of examples isolating some of the major failures

THE boiler, turbine, piping and equipment components in a power plant are generally designed, constructed and fabricated under various applicable Codes and Specifications. Although normally the best design know-how and high-quality fabrication methods are considered essential, failures are not uncommon. Whereas many failures can be repaired at relatively low cost, others have been very costly in requiring the shutdown of the power plant, which may result in a financial loss varying from $8000 to over $15,000 per day. Modern steam power plants employ steam at tempera-

* Presented during 1960 National Fall Meeting of the Society for Nondestructive Testing, Philadelphia, Pa., October 19, 1960.
† Metallurgical Engineer.



A B

Fig. 1—Comparison of radiographic exposures made with (A) Cobalt 60 where nothing shows is contrasted to (B) X-ray equipment of pipe section revealing considerable cracking in inside surface of pipe

tures of over 1000 F and pressures of several thousand psi. Failures of piping, valves, fittings or other components involving sudden ruptures have, in some instances, resulted in a loss of life. Serious failures have also occurred in turbine shaft ruptures, pipe supports and hangers.

By far the majority of failures develop gradually. Most common is the initiation of a crack followed by its gradual propagation under the influence of thermal or mechanical fatigue or shock, corrosion, erosion, creep, etc. More rare are failures in which the metal itself has become brittle without cracking actually occurring. A thermal or mechanical shock may then cause sudden rupture. The latter types of failures usually are the most disastrous. Therefore, early detection of potential or developing failures is of utmost importance in order to avoid costly losses of power production or loss of life.

Inspection, unfortunately, is still in its infancy and is not adequately understood by a great many of those who specify inspection techniques or equipment.

In many instances costly repairs have been made in equipment, piping or tanks where defects were of such minor magnitude that failure would have been extremely unlikely. However, there are also a number of instances where detectable serious defects were not observed simply because the inspector did not use the proper equipment or operated the equipment incorrectly. For example, Fig. 1 illustrates two radiographs made with Cobalt 60 and X-ray sources, respectively, of a length of pipe containing cracking. The severe cracks present and so visible by X-ray means were not detected with Cobalt 60 radiation sources. Radium also did not reveal effectively the cracking.

Good inspection equipment is available. However, it is essential that the inspector fully understands the characteristics, advantages and limitations of the equipment and applicable inspection methods. It is also essential that the inspector be familiar with the various types of defects which may be present in the equipment which he is examining. Finally, he must know the materials involved, their relative tendency toward embrittlement and crack propagation at room and service temperatures, and must be able to interpret whether or not a defect is critical. Proper interpretation must consider also the effects of service conditions, fatigue, creep, corrosion. Few inspectors have received this type of training.

Without this training a minor non-critical defect may be removed at substantial cost, only to be replaced with a far more critical condition which in time may result in a costly or disastrous service failure. For example, where repairs are made by welding, the repair may represent a severe notch or may result in a damaging effect on the adjacent base metal caused by the welding or subsequent heat treating operation.

Numerous papers have been written on the operation and mechanics of inspection equipment and techniques. Rather than follow this procedure here, the application and limitations of available equipment shall be reviewed from the point of actual service failures encountered and their interpretation.

It must also be recognized that frequently non-destructive testing techniques may indicate only an "area of suspicion" or may miss a hazardous condition altogether. Destructive techniques may then be necessary to supplement the non-destructive tests performed.

Causes of Service Failures

The conditions responsible for a service failure usually can be divided into five categories (1, 2).[1]

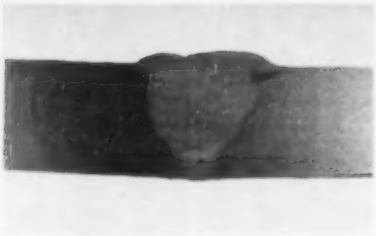
(1) design
(2) material selection, specification and handling
(3) manufacture, forming and shaping of materials
(4) assembling, joining and welding
(5) excessively severe service conditions

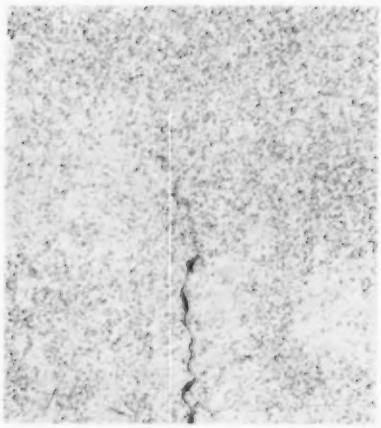
[1] Note: Figures in parentheses refer to similarly numbered entries in the BIBLIOGRAPHY at the end at the article.

(A) Fused root pass (B) 1/8 in. deposited filler metal (C) 1/4 in. deposited filler metal

Fig. 3—Series of X-ray radiographs illustrating the "disappearance" of a centerline crack with increasing weld-metal thickness in 1 1/4 Cr-1/2 Mo alloy

Fig. 4—Photograph of etched cross-section of weld joint in Fig. 3 illustrating crack in weld root pass below and right





In some instances two or more conditions may combine to cause a service failure.

Since the same conditions may cause failures in parts of a boiler, in piping, in valves, in the turbine or other equipment, and may be detected with the same inspection equipment or techniques, this discussion will approach inspection from a consideration of some of the major defects encountered. Moreover, only the major types of inspection equipment commercially available will be considered. For more highly specialized equipment and techniques the Nondestructive Testing Handbook should be consulted (3).

Equipment

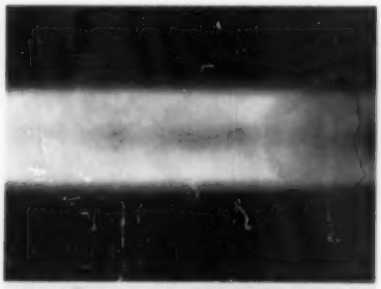
Commercial inspection usually involves inspection by (1) radiography with X-ray and radioactive isotopes, (2) ultrasonic inspection, (3) dye penetrant inspection and (4) magnetic particle inspection.

Radiographic Inspection

Although radiographic inspection with portable X-ray sources is feasible and is occasionally done, inspection with Radium sources or radioactive isotopes such as Cobalt 60 or Iridium 192 is far more common, Fig. 2.

The ASME Boiler and Pressure Vessel Code, the ASA Code for Pressure Piping, applicable ASTM specifications and other standards unfortunately make only little or no distinction between these methods—usually mentioning only "radiographic examination." The differences, however, are significant. Other critical variables which may determine whether or not a defect is detected involve orientation of defect, film grain, position of source, size of source.

However, even with the most favorable techniques defects may not necessarily be detected by radiography. The difficulty in determining cracks in welds is illustrated



(D) 3/8 in. deposited filler metal

(E) 1 1/8 in. deposited filler metal (weld complete)

(Fig. 3A—Final two radiographs show completed weld of Fig. 3, p. 25)

Fig. 5—Iridium 192 source positioned on outside of pipe for radiography of opposite pipe wall with film placed on water-cooled "hot-radiography" film holder

in Fig. 3. The root pass in the 10 in. Schedule 160 (1.125 in. wall) $1^1/_4$ Cr - $^1/_2$ Mo pipe was made by inert-gas tungsten-arc root-pass welding. The root pass weld contained the $2^1/_2$ in. long crack shown on the X-ray radiography in Fig. 3A. As is common practice, the subsequent weld passes were made by shielded metal-arc welding. After the second shielded metal-arc weld pass, the crack in the root of the weld no longer was detectable, Fig. 3C. The "disappearance" of the crack was caused by the shrinkage of the first covered electrode pass which drew together the root crack. Certainly, the potential danger of such cracks has not been lessened by their being closed up mechanically, Fig. 4, despite the reassuring appearance of Fig. 3A, p. 26.

Nevertheless, many cracks or defect conditions can be determined by proper radiographic techniques.

Frequently specialized auxiliary equipment is also necessary. For example, where a failure has occurred in power plant piping, it is generally desirable to explore the extent of cracking. Since shutdown time is extremely costly, it is advantageous to conduct the radiographic inspection as soon as possible. Normally, about 15 to 24 hrs. are required before a steam pipe cools to room temperature (at least below 120 F) before it is possible to place the radiographic film on the pipe surface. However, by means of "hot-radiography" film holders (4) it is possible to perform radiographic inspection within a few hours of the shutdown of the steam piping, Fig. 5.

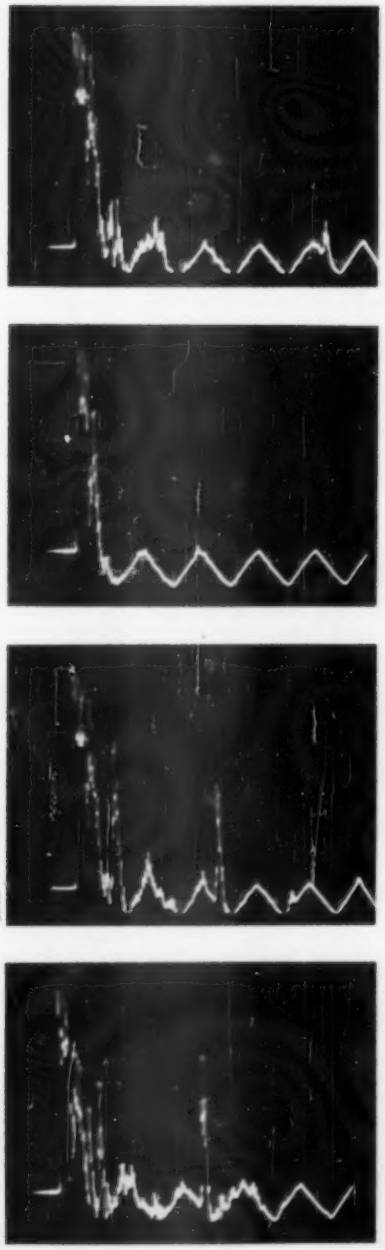


Fig. 7—Ultrasonic wave patterns caused by different root conditions in weld joint (A) normal pattern at contact with pipe surface, (B) pattern from pipe butt weld made with inert-gas tungsten-arc root-pass—acceptable, (C) pattern from machined edge at root of pipe weld—acceptable, (D) pattern representing lack-of-penetration in root of weld deposit—unacceptable

Ultrasonic Inspection

Fig. 6—Ultrasonic inspection of pipe joint for defects in weld deposit by shear wave technique

Ultrasonic inspection, Fig. 6, for potential failures in piping is still not extensively done. One problem is that only a few commercial laboratories have developed the large number of tests and correlation standards necessary to permit proper interpretation of the many different conditions that can occur. Particularly, in weld joints

Fig. 8—"Destructive" removal of boat-shaped test section by means of weld prober saw to determine seriousness of defect located by ultrasonic inspection

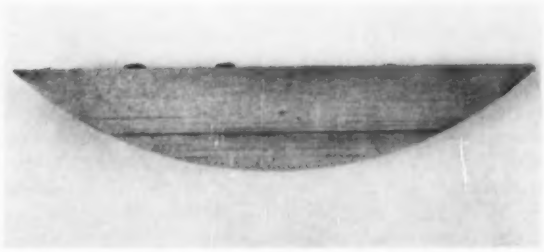


Fig. 9—Cross-section of lamination in seam welded pipe in the direction of rolling of the original plate

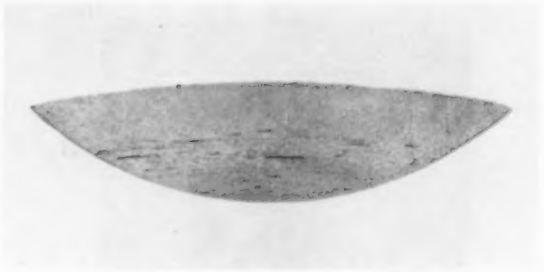


Fig. 10—Cross-section of same lamination as shown in Fig. 9, but transverse to the direction of rolling of the original plate

involving internal weld build up, where flat or taper machining, backing rings or consumable inserts, variations in surface effects, and many others affect the ultrasonic pattern [illegible]icated on the oscilloscope. For example, a properly welded backing ring may produce the same pattern as unacceptable lack-of-penetration or root cracking. Fig. 7. Only an experienced inspector may be able to differentiate between potentially serious

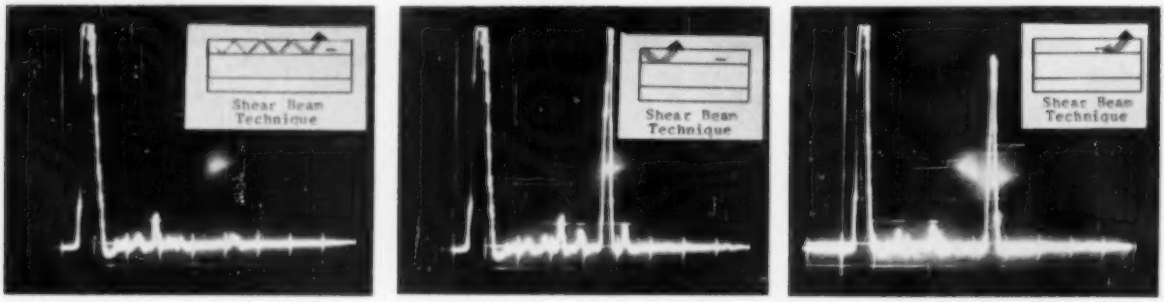
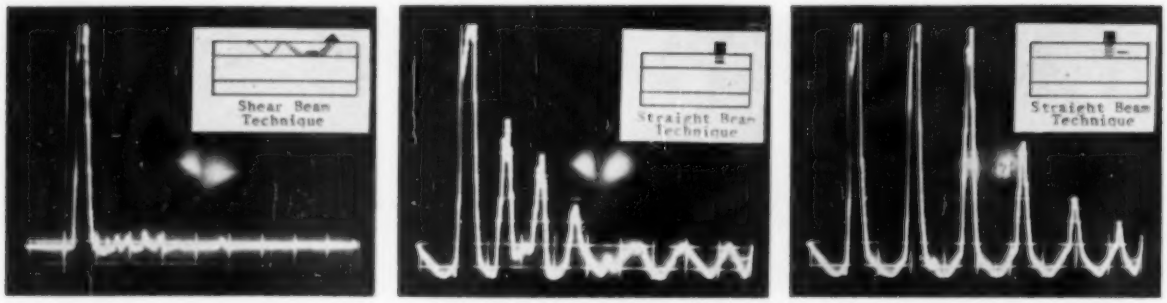


Fig. 11—Ultrasonic wave patterns of an internal lamination corresponding to varying locations of ultrasonic crystals



defects and minor non-critical discontinuities such as porosity, slag, changes in surface contour and metallurgical structure. At times other non-destructive or destructive techniques may be necessary to supplement the interpretation of the ultrasonic indication. This may be far less costly than the removal of a minor unimportant non-homogeneity in the steel.

Steel nearly always contains certain internal non-homogeneities. The great majority of these have no significant effect upon the mechanical properties or service life of the metal. These non-homogeneities also tend to vary from one steel product to another, such as in castings, forgings, extruded pipe, rolled pipe, etc. On seam-welded pipe, for example, samples removed by "weld probing," Fig. 8, occasionally reveal laminations of a stringer type as illustrated in Fig. 9. Since most plate products have directional properties, these stringers may appear long when the samples are cut in the directions of rolling, Fig. 9, or narrow when the samples are removed transverse to the direction of rolling, Fig. 10. Because the stringers frequently occur in clustered grouping, it is generally impossible to ascertain ultrasonically with any confidence whether the laminated area is critical and rejectable or not. The ultrasonic patterns corresponding to Fig. 10 are shown in Fig. 11.

Shrinkage cavities in castings not of a critical magnitude are frequently also difficult to interpret and separate from more serious defects that are propagating into service failures. Similarly proper interpretation of the soundness of turbine casings, steam headers, etc. may not be conclusive by ultrasonic means.

Dye Penetrant Inspection

Dye Penetrants are also being used, particularly when narrow cracks are suspected in the surface of shafts, on the inside of turbine casings, Fig. 12, where stress corrosion may have occurred in instrument tubing, boiler feed piping, or boiler tubing, Fig. 13, etc.

Fluorescent penetrant inspection, Fig. 14, may be necessary where the suspected cracking is very fine, Fig. 15.

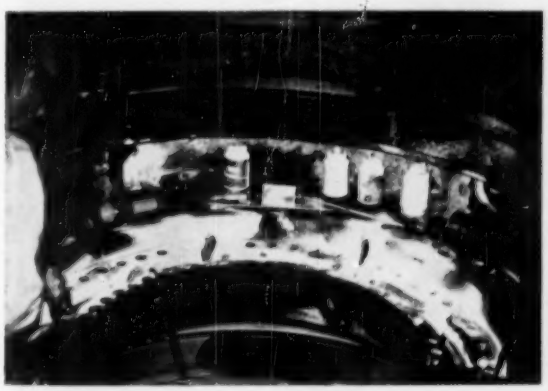


Fig. 12 - Inspection of inside of turbine casing for cracks, with some cracks already partially ground out

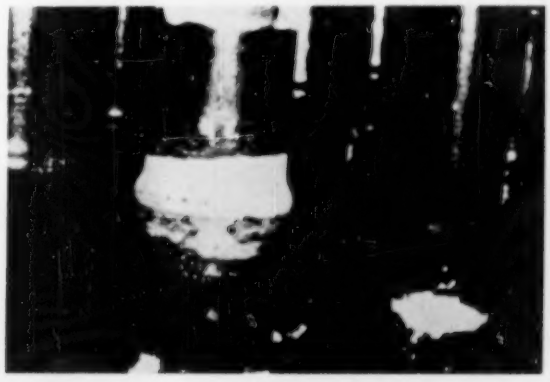


Fig. 13—Dye penetrant indications on boiler tube joints, indicating poor fusion in pressure welds

Fig. 14—Fluorescent penetrant inspection of valve body and weld for fine cracks

Fig. 15—Fluorescent penetrant of crack in valve base metal adjacent to butt weld

Fig. 16—Magnetic particle inspection for evidence of cracking in pipe butt weld employing cable from welding generator to produce magnetic field in pipe weld area

Fig. 17—Magnetic particle inspection of pipe weld joint with prod fixture

Magnetic Particle Examination

Magnetic particle testing may be done either by using an electric current to induce a magnetic field within the test specimens or by placing the test specimen within a magnetic field. A cable from a welding generator may be wrapped around the area to be inspected Fig. 16, or the area may be located within a magnetic field from an electro-magnetic prod fixture, Fig. 17.

(A) (B) (C)

(D) (E) (F)

Fig. 18—Magnetic particle examination of crack by (A) and (B) current flowing through pipe between copper prods, (C) and (D) "looped coil" technique and (E) locating pipe section containing crack in magnetic field (F) represent X-ray of area containing cracking

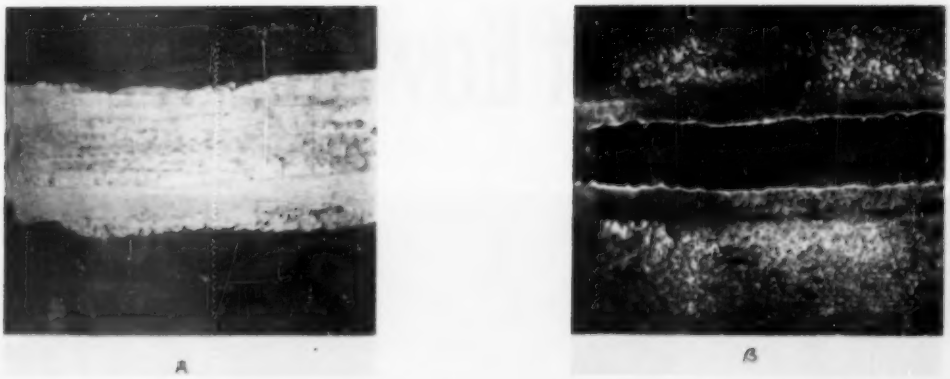


Fig. 19—Fluorescent magnetic particle inspection of stress corrosion cracks in pipe weld under (A) ordinary light and (B) ultraviolet light

Typical test methods are shown in Fig. 18. Fig. 18F is a radiograph of a defect in a nozzle weld. Figs. 18A and 18B illustrate magnetic particle indications with the electric current passed directly into the piece where the direction of the current flow determines the amount of cracking observed. Figs. 18C and 18D illustrate the somewhat greater difficulty of detecting cracking in this type of joint with the "looped coil" technique. Fig. 18E shows barely visible a crack indication with the electro-magnetic prod fixture.

For the detection of extremely narrow cracks the application of fluorescent magnetic particles in a liquid medium (usually water) is one of the most revealing techniques Fig. 19 illustrates detection of stress corrosion cracks in a pipe weld under (A) ordinary light and (B) ultraviolet light.

On piping by far the majority of service failures originate from defects along the inside diameter of the pipe. Thus, the inspection techniques evaluating the soundness of the underside of a weld should be considered at least as significant as the surface inspection techniques. However, in repair, magnetic particle inspection techniques are useful in "chasing out" cracks.

These techniques are also important during the repair of the defective area. Where cracks have occurred which are being ground out, the "removal" of the crack can be confirmed with these techniques.

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Air Lifted Nuclear Power Plant in Transit

The first nuclear power plant for the Air Force, prefabricated into 16 packages, took to the air in early June for a 1700-mile trip to a Wyoming mountain top. The plant, incorporating a pressurized water reactor, was built for the Air Force by the Atomic Energy Commission under a joint program of the Commission and the Corps of Engineers. The Martin Company, Baltimore, was prime contractor for the plant, designated PM-1 (Portable Medium Plant No. 1).

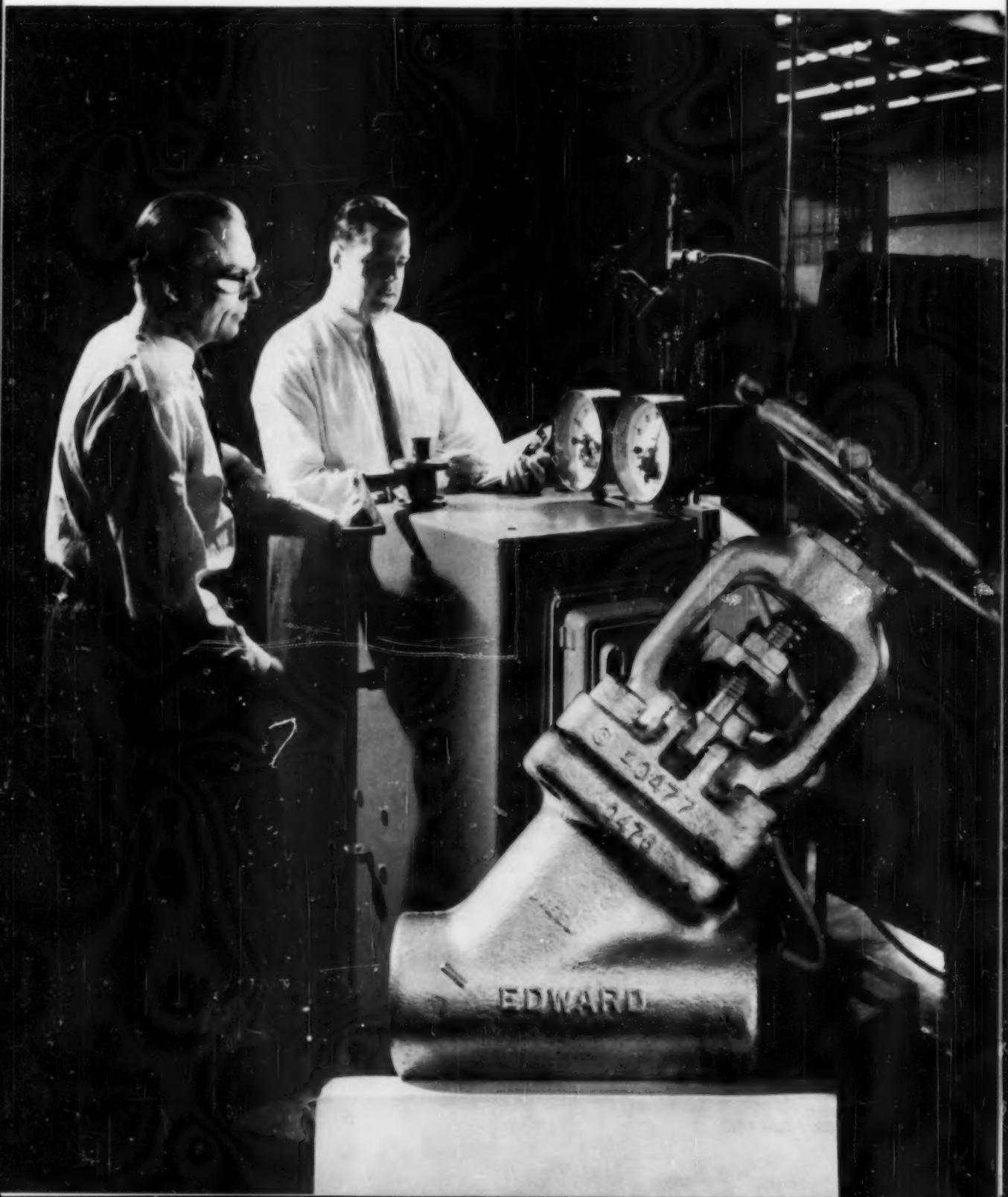
The reactor is scheduled to achieve criticality (sustained chain reaction) in September. It will be cooled and moderated by light water and will be fueled with highly enriched uranium. When operational in 1962, it will provide 1000 kilowatts of electrical power and 2000 kilowatts of heat for the 731st Radar Squadron of the Air Defense Command, 29th Air Division, Semiautomatic Ground Environment (SAGE). The plant will provide engineering and operating data for the design of improved nuclear power plants which can be used at Air Force installations.

The PM-1 was designed to provide for factory-assembled modules or packages both for air transportability and for quick assembly so that nuclear power can be made available any place in the world where Air Force units may be needed. The package design also allows the plant to be disassembled and relocated. The largest packages are 8 ft 8 in. × 8 ft. 8 in. × 30 in. and weigh less than 15 tons each.

The Commission will install and test operate the plant for six months before transferring it to the Air Defense Command for operation. Coordination of the development program for the PM-1 within the Air Force has been the responsibility of the Air Force Systems Command's Electronics Systems Division at Hanscom Field, Bedford, Massachusetts, and the AFSC's Special Weapons Center at Kirtland Air Force Base, Albuquerque, New Mexico. The Special Weapons Center will supply engineering support to the Air Defense Command.

The operating crew for the PM-1 includes 17 airmen under the supervision of an Air Force officer. All crew members have received extensive nuclear power plant operating and maintenance training and experience in AEC-Department of Defense nculear power training programs and are certified nuclear plant operators. The crew has been augmented by two qualified servicemen each from the Army and the Navy. The crew has accumulated a total of over 80 years of reactor operating experience.

The Story of Edward Research



and the "Perfect" Globe Valve

Edward designers built the Figure 848 forged steel globe valve from scratch. In an art where most development effort must be directed toward modification, adaptation, and refinement of existing technology, the 848 story is almost unique. The objective was simple: To design and construct a perfect 600-lb-class globe valve in the ¼" to 1" size range. (Basic rating 600 lb at 910 F, 2000 lb WOG.) That the project was virtually successful is a tribute to the ingenuity of the Edward Research Staff and the equipment which enabled them to validate their progress. Here, is that story.

Three areas were given special consideration by the Edward staff of engineers and metallurgists when they set out to design a "perfect" valve. They were: 1. Body Shell and Bonnet Joint; 2. Seat Tightness; 3. Packing Area. Although each area was treated separately, the relationship of one to the other was a factor that had a great deal to do with the outcome of the project.

A series of "torture" tests such as the pressure pulsator shown on the opposite page carried each part and joint to the point of destruction. Thus Edward designers were able to trace each weakness to its source. Perhaps no other valve ever designed has been known and understood so well by the men who designed it.

1. BODY SHELL AND BONNET JOINT. The valve bonnet was bolted finger tight; it tested at 2000 psi. Then, at full design tightness on all four bolts, the bonnet joint did not leak until 11,000 psi (5½ times design pressure!) was applied. Next, 8000 psi applied 100 consecutive times produced no apparent valve damage. Internal pressure was pulsated from 200 to 2000 psi for 10,000,000 cycles with no apparent damage!

The bonnet cap screws were subjected to 350% of design tightness before failure occurred. Further evidence of design effectiveness was the unpredictability of failure. In one case the threads stripped; in another the bolts broke off, and in other there was excessive bending of the bonnet flange. There was no *one* apparent point of weakness!

2. SEAT TIGHTNESS. Similar destructive tests were conducted on the valve stem and seat. The valve required on 65% of standard test closing torque to seal tight at 2000 psi. And 350% of standard torque was built up before the stem sheared below the handwheel. 100 operations at 2½ times standard torque did only negligible damage to seating surfaces. Even after this test only 90% of standard test torque was needed to hold 2000 psi.

3. PACKING AREA. Six times as much load as actually required to seal the packing chamber was applied to the gland bolts without causing damage. A load 3½ times greater than required for sealing was applied 50 times, also without causing damage.

Thus the "perfect" globe valve was designed; perfect not because it can't fail, but perfect because it has no apparent weaknesses. The full design and construction story is told in Edward Catalog 14-G.

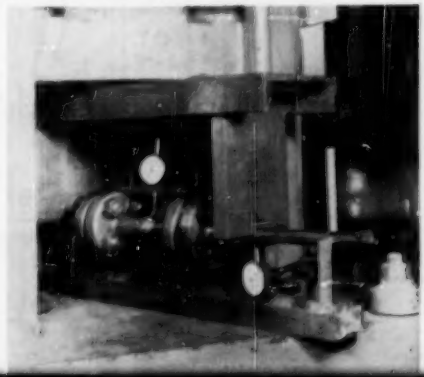
Edward builds a complete line of forged and cast steel valves from ¼" to 24" for industrial, marine, petroleum and technological services. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

EDWARD STEEL VALVES
another fine product by
ROCKWELL

Chief Engineer C.A. Siver and Design Engineer Don Easton observe effects of pulsating pressure on newly designed Figure 848 forged steel globe valve in Rockwell-Edward Research Lab.

Rugged forged steel body . . . combined with high-strength stainless steel gland bolts and bonnet bolts, aluminum-bronze alloy yoke bushing, asbestos-stainless spiral gasket and other premium features . . . makes the Figure 848 a virtually "perfect" small steel valve.

Test arrangement produces uniform bending moment on valve and ½" pipe. Test shows that the strongest pipe likely to be attached to the valve will yield with less than ½ the bending moment required to distort body.



In Furnace Protection . . .

A Big Step Forward?

Take a serious problem—multiburner flame scanning, mix in optical know-how and a new glass fiber technology, provide catalytic Yankee ingenuity and you touch off what looks like a revolution in the art of avoiding furnace explosions

THERE are problems—and they are tough ones—in protecting boiler furnaces against the explosion hazard. Each year too many lives are lost and too many millions of dollars wasted because of our failure to furnish adequate safeguards. It's common knowledge that excellent detectors are available to verify the existence or absence of flame. Trouble arises in two ways when applying these detectors: failure to protect against causes other than loss of flame and failure to apply flame detectors so that they can function properly. (Failure to prove flame quantitatively is beyond the scope of this article.)

Single Burner Application

A flame detector must "see" the flame it is designed to protect—and it should "see" no other flame. This would seem to be a relatively simple problem in a single burner arrangement but it is simply not so. Conventional packaged water tube boilers in general have had a flame scanner mounted in the burner front "looking" along the burner axis as in Fig. 1(A) or in the rear furnace wall as in Fig. 1(B). Both of these common applications neglect the possibility of the flame front moving away from its proper origin. Many design shortcomings and system malfunctions can cause the flame front to move radically out into the furnace but the flame detectors (Fig. 1(A) or 1(B)) cannot sense this hazard. A flame scanner sighted as in Fig. 2 would protect against this hazard but would probably require a second scanner, (shown dotted) for pilot proving. In any of these scanner applications the final adjustment (control over what the scanner "sees") is left to the discretion of the start-up service engineer, who might not be either a burner or a safeguards expert.

The Headache Worsens

The scanner application problem grows much more complex when we try to protect a furnace with more than one burner. Trick here is to prevent the scanner protecting Burner A from "seeing" the flame from Burners B, C, D, etc. If Burner A's scanner *does* see flame from Burner B, two problems arise:

1. If Burner B has been lit off first we cannot start Burner A. A fail-safe requirement for flame safeguards demands that they be unable to start if they "see" flame before they're supposed to.
2. If both burners are in service, Burner A could lose ignition and pour raw fuel into the furnace without any indication of failure. It continues to function on the flame signal it picks up from Burner B.

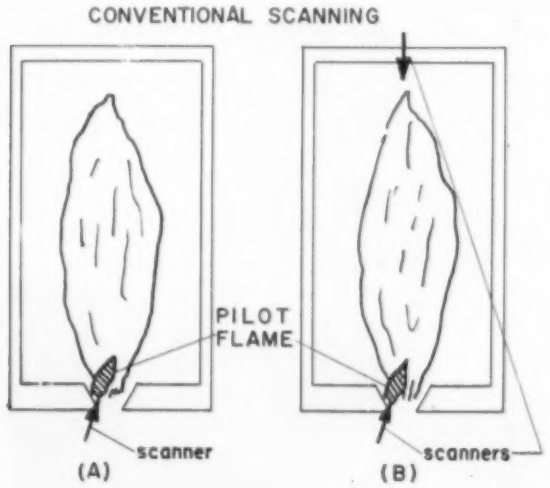


Fig. 1—Conventional scanner arrangement

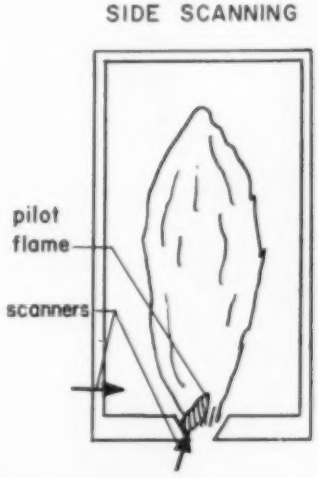


Fig. 2—Side scanner arrangement

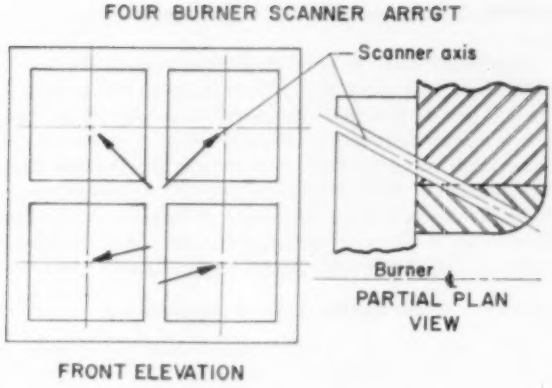


Fig. 3—Multi-burner scanner arrangement

Naturally as more burners enter the picture the protection problem becomes increasingly difficult. Schemes for sighting scanners such as shown in Fig. 3 are used to combat the problem. This type of approach has several drawbacks.

1. It is difficult and expensive.
2. It divides the responsibility for proper flame scanning among several workmen and supervisors.
3. Variations in furnace shape, flame pattern, and firing conditions prohibit standardization.
4. Scanner sight tubes angled upward are dirt and water traps.
5. Ultimate responsibility for proper operation of the safeguard system is frequently very difficult to assign.
6. Costly field changes are required in many cases.
7. The ultimate in protection is seldom realized.

Discrimination may be defined as a scanner's ability to "see" its own burner flame to the exclusion of other burner flames. One hundred per cent discrimination means that scanner A will pick up a flame signal from Burner A, and only Burner A, up to 100 per cent of boiler rating. So difficult is this problem that the insurance companies (though they'd love to have 100 per cent) will accept failure to discriminate above 50 per cent of boiler rating. Enforcing 100 per cent discrimination, while highly desirable, has proved impractical. The lower figure is accepted in the fervent hope that a burner which loses ignition will reignite from adjacent burners above 50 per cent rating. It doesn't always happen.

Man with a Problem

Faced with the problem described above was Mr. B. W. Devine, Chief Engineer of American Optical Co.'s power plant at Southbridge Mass. His principal boiler, making steam for power generation, process and heat is front-fired by four register type, circular burners in a two up, two down arrangement similar to Fig. 3. Gas and oil are fired and the scanner sighting arrangement is shown in Fig. 4. As you might expect from reviewing the check list above, there was more than a little difficulty attendant to getting the system into proper operation. Since American Optical generates its own power, reliability of service is a prime factor. Safety and reliability are not incompatible but harmony is often difficult to achieve. Since currently available flame scanning schemes didn't offer a satisfactory solution, Mr. Devine undertook to do something about it.

An Ingenious Approach

Fig. 5 illustrates how this new attack goes right to the heart of the problem. A fused quartz rod is inserted in the burner tile and "looks" across the axis of the burner at the point of origin of the flame front. This point should also coincide with the intersection of pilot and main burner flames so that the quartz rod can pick up either or both flames. Flame scanner can be located away from heat and dirt at the end of the quartz rod. We observed the operation of this arrangement with a conventional lead sulfide cell flame detection system. There was no observable loss in signal strength. Flame pickup and light transmission were excellent for both gas and oil flames. Burners all around the test burner were lit off and the test burner then cut off. Perfect discrimination was obvious—signal strength dropped immediately. To us it seems that this method of scanning has at least the following advantages:

1. Burner tile geometry (Fig. 5) limits flame pickup from other burners. Line of sight could even be angled back away from furnace to make discrimination even more positive.
2. Fused quartz rod has excellent transmission of light impinging normal to its face (end), but transmission drops off very rapidly as angle to the normal increases. This of course further lessens probability of stray light pickup.
3. The line of sight is where it should be—across the burner axis through the proper flame front origin.
4. A life of several years is predicted for the quartz rod at temperatures up to 2000 F.

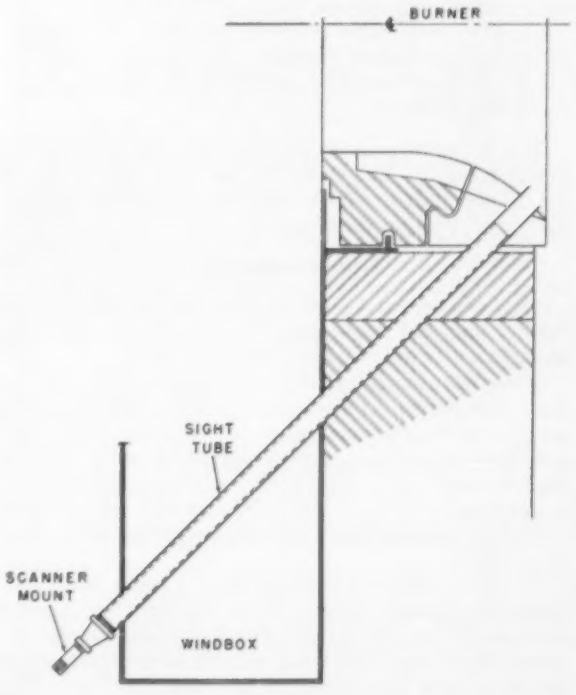


Fig. 4—Conventional scanner mounting

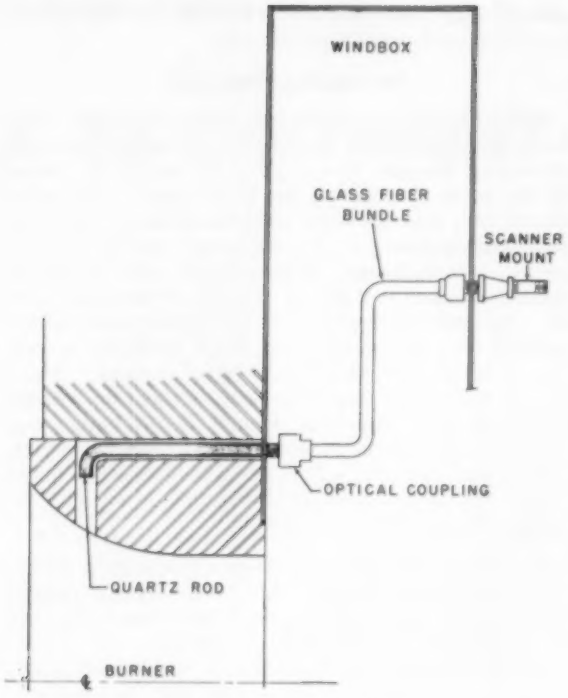


Fig. 5—Proposed scanning set-up

5. Dual rods can be installed at low cost and paralleled with a simple optical coupling (see Fiber Bundles below) so that cleaning or maintenance need not affect operation.
6. *Burner manufacturers can arrange for standard installation of flame scanners regardless of furnace dimensions, flame shape, burner location, etc. This could mean insurance approval of a burner, ignitor, scanner package. The industry will have taken a great stride forward when this last is accomplished.*

This is the story as we saw it demonstrated at Southbridge recently. We think it holds tremendous promise for the near future. We'll naturally follow developments and report them in these pages.

Fiber Bundles Help

The basic approach outlined above can be carried much further and find application in more difficult locations through a new technology called Fiber Optics.

When light shines on the end of a glass rod, much of the light that enters is reflected many times from the walls and is finally transmitted to the far end. This phenomenon occurs even in very fine fibers until the fiber diameter decreases to near the wave length of light (about 5 microns). A glass fiber 50 microns in diameter (0.002 in.) acts just like a rod in transmitting light but is very flexible.

Of course this development did not occur overnight. American Optical scientists tell us that very high quality fiber surface is required and that to prevent leakage between fibers, each is sheathed in a thin transparent jacket having a lower index of refraction than the fiber. The wonder of this development is that as many as 25,000 fibers have been drawn into a single bundle only 2 mm in diameter.

Loss in intensity of light in transmission through such a fiber bundle is about 50 per cent in seven feet so that at the end of a 14 ft bundle we would have only 25 per cent of our initial intensity. Transmission of infrared and ultraviolet wave lengths is reported to be somewhat less efficient. However, in a test we observed where flame pickup was made by quartz rod plus 18 in. of fiber bundle we could not see any diminution of the flame signal as compared to the flame scanner alone.

Fiber Bundle-Scanner Application

Obviously the above offers interesting possibilities in applying flame scanners. By using fiber bundles the flame signal may be transmitted from the quartz rod pickup, around corners, through ducts, etc., to a location where the scanner can be mounted in a dirt-free, low ambient temperature location. Fiber bundles, we are told, function normally with long life in temperatures up to 600 F. From 600 to 800 F operation is unaffected but the stable life begins to decrease. Operation in atmospheres above 800 F is not recommended. Another use of the fiber bundle would be to couple a second quartz rod flame pickup as a spare.

Coherent Fiber Bundles

Thus far we have been discussing bundles of glass fibers in which the fibers lie in random arrangement. These are called "*incoherent bundles.*" When fibers are gathered in an orderly arrangement so that fibers at both ends are in the same relationship to each other we have a "*coherent bundle.*" Coherent glass fiber bundles will transmit images with startling clarity of detail. We found the experience much like viewing a scene from inside a screened porch—the image is reproduced by a series of small "dots" of light and shadow-color transmission is excellent. Fig. 6 is a photograph of the face of a meter *photographed through a coherent fiber bundle.*

An application for coherent bundles that immediately suggested itself was in television viewing of furnace conditions. It would seem that the furnace roof openings could be considerably less expensive, that cooling requirements would be much less and that cameras could be located some distance away from the opening in a cooler, cleaner atmosphere. The cost of television applications could be materially reduced by use of this new technology unless the application develops "bugs" we do not visualize at this writing.

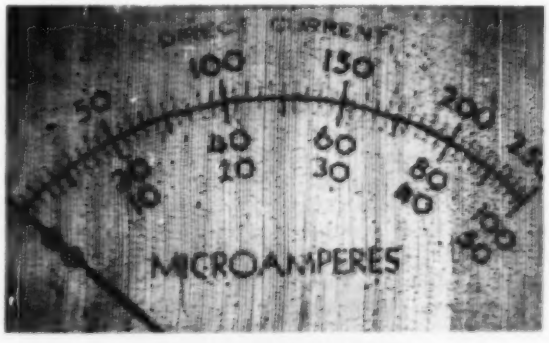


Fig. 6—Meter photographed through fiber bundle

What Lies Ahead?

The basic principles have been clearly demonstrated in what appears to be a great forward step in furnace protection. The mechanics of application remain to be worked out. Similarly the limitations of the new system must be established. Reader Devine is going ahead with the application of his scanning method on all four burners of his principal boiler. Peabody Engineering, who furnished burners and flame safeguard system, and Combustion Engineering, who built the boiler, will be interested observers as installation and testing progresses.

We prefer not to think of this step as a breakthrough—we've come to dislike that overworked word—but as a very promising development brought about by a clear-thinking approach to a nasty problem. We're certain that Mr. Devine's initiative and ingenuity, backed by the imagination and perseverance of American Optical scientists are going to prove of immense value to a long-suffering industry. In keeping with COMBUSTION's continuing exposure of the safeguard problem, we shall report further on this approach as developments occur.

Remote Control Thawing Station Helps Utility Stockpile 90,000 Tons

Despite one of the worst winters on record, the Baltimore Gas and Electric Company completed winter stockpiling operations at its new Charles P. Crane Station on schedule. Stockpiling of some 90,000 tons of coal continued without interruption through the coldest weather of the season.

The Charles P. Crane Station is scheduled for commercial operation early in the summer of 1961. The first unit, one of four planned for this site, will consume some 65 tons of coal per hour under full-load operation.

A one-man thawing station, said to be one of the most "automated" of its type installed to date, enables the company to thaw up to 10 cars an hour. The 225-foot-long thawing facility handles five cars at a time.

Thirty-six prefabricated thawing pits are so arranged that any size car, or any combination of sizes in a five-car train, can be thawed effectively without damaging the cars. Each pit radiates heat at the rate of 1.5 million Btu per hour. The arrangement of the pits makes available to each car as much as 6 million Btu per hour.

This thawing station was designed and engineered cooperatively by Hauck Manufacturing Company, Brooklyn, N. Y., and the Baltimore Gas and Electric Company to meet the specific requirements of the Charles P. Crane Station.

Winter stockpiling for this Station involved a thawing problem not faced by stations receiving their coal by barge. The Charles P. Crane Station is one of two in the Baltimore Gas and Electric system that receive coal directly by rail. Because of the cold weather, thawing was required before the cars could be dumped and the coal sent on conveyor belts to the stockpile. The cars had to be unloaded and released in a reasonable length of time if demurrage was to be avoided.

The specially-designed thawing station that contributed measurably to stockpiling the initial 90,000 tons is operated from three remote control panels. The operator simply pushes buttons to start up the individual thawing pits he wishes to use. In the event of failure of air pressure or of fuel or power supply, shut-off is automatic. This feature, plus remote control, virtually eliminates the injury hazard to operators existing in some non-automatic systems.

The panels from which the pits are individually controlled are installed on a trackside windbreak. The first step in a thawing operation is manually igniting all pilots. The pilots remain in service as long as desired so that the operator will get instantaneous response from any pit he may decide to use.

Because of the large number of pits and their control by pushbutton operation, radiant heat can be provided immediately to key areas reagrdless of the makeup of the train. Determining which pits are to be used for thawing depends on the size of the cars.

The operator takes his cue from the lead car. This car is properly positioned over the pits to establish a point of reference. After this is done the operator need only observe the position of the cars along the track and start up those pits that are located under areas to be heated.

This flexibility of operation not only speeds thawing and saves fuel but also avoids damage to the hopper cars. Any thawing pit beneath a car section vulnerable to damage by heat is not operated.

Hauck thawing equipment at Baltimore Gas and Electric is oil-fired since gas is not available at the Charles P. Crane Station site. No. 2 fuel oil, pumped from the power plant storage tank, reaches the burners via underground pipeline. Air needed for oil atomization and combustion is provided by low-pressure air blowers.

Each of the 36 prefabricated pits, rated at 1.5 million Btu per hour, contains two burners, a pilot and safety equipment. The pits have hinged, split covers that fold back readily during thawing operations. The covers remain closed to protect the pits when not in use. The burners and controls are protected by individual covers.

Use of prefabricated pits can reduce considerably the cost of installation of a thawing station. Prefabricated pits require no underground form work. At the time the pits are installed a railroad tie is removed from each pit location. No other alteration to the track is necessary. When a thawing station is planned in conjunction with new track, as in the case of the Baltimore Gas and Electric facility, ties are omitted where the thawing pits are to be placed.

Power for Texas

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REPUBLIC ELECTRUNITE BOILER TUBES were fabricated at Wickes Boiler Company in Saginaw, Michigan, shipped to Bryan, Texas, for power plant installation. Strict ELECTRUNITE tolerances and production control provided precise fit at job site.

REPUBLIC ELECTRUNITE BOILER TUBES

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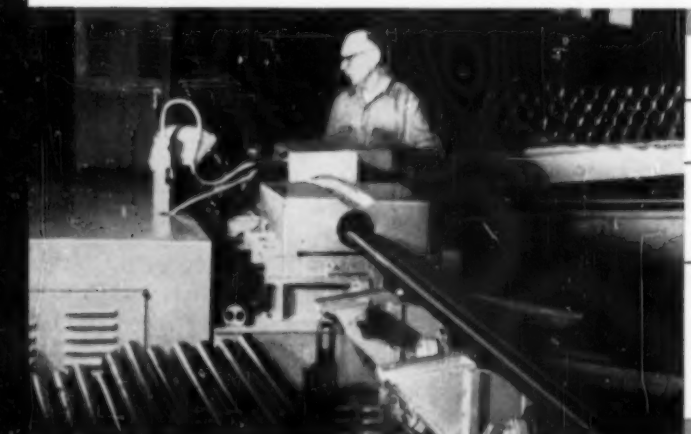

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FARROWTEST REJECT TABLE

Wall Thickness (B.W. Gage)	Minor dimension of the defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	.006"	.0025 sq. inches
18	.006"	.003 sq. inches
16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.

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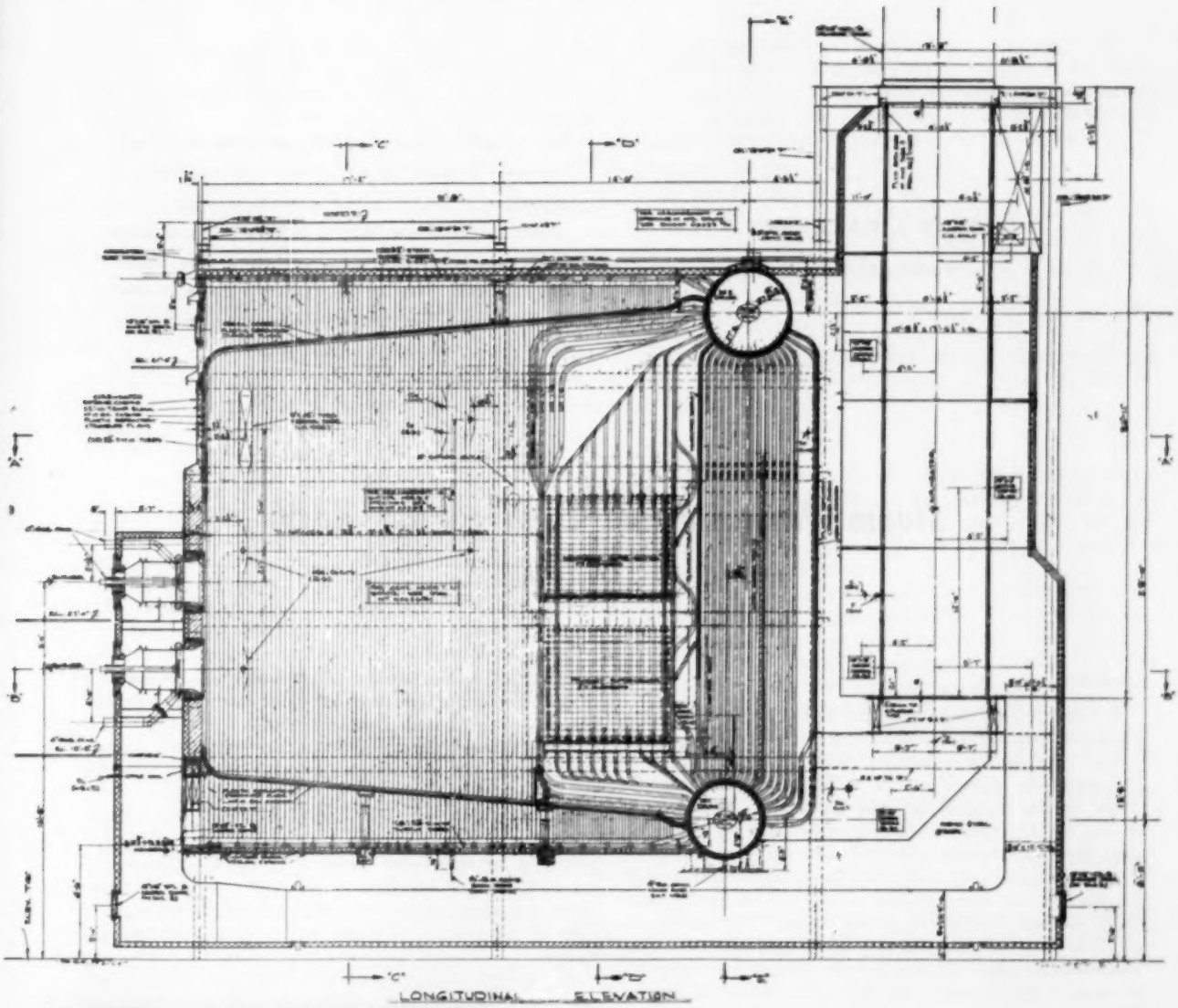

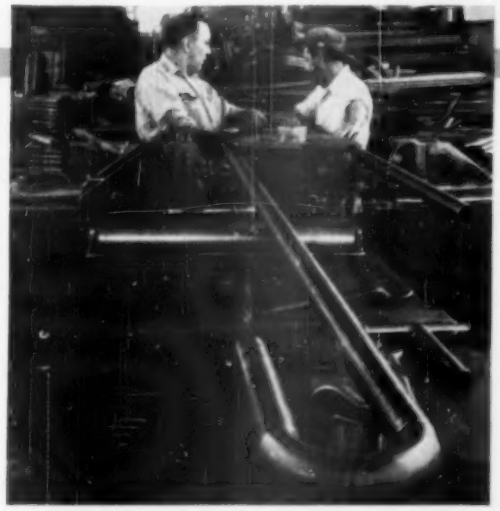

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By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers

Steam Power Plant Clinic—Part XXIV

QUESTION

We had ordered three so-called half-capacity boiler feed pumps to serve our new 150,000 kw turbo-generator. Each pump is designed to handle 700,000 lbs of feedwater. Originally, the pumps were to be motor driven at constant speed, but shortly after the order was placed, we decided to change the arrangement and the order included hydraulic couplings to permit operation at variable speed.

After the pumps were installed, we discovered that through an oversight the manufacturer of the recirculation by-pass orifice had not been advised of this change. The nameplate on the orifices indicates that they are designed for the rating recommended when the pumps were to have been operated at constant speed, namely 300 gpm and 6000 feet differential pressure.

Are these orifices suitable for this installation or will the quantity of by-pass flow that they will handle with reduced speed operation at light load be inadequate to protect the boiler feed pumps against overheating?

ANSWER

You need have no concern over the by-pass orifices. Actually, they are more than adequate for variable speed operation, as you will see presently.

The purpose of a recirculation by-pass is to provide sufficient flow through a boiler feed pump at all times to remove the heat generated within the pump through the transformation of the pump losses into heat.

This recirculation line leads from the pump discharge to some point in the system where this heat can be dissipated—for instance to the deaerator at the pump suction. A by-pass orifice is located within this recirculation line and is used to take the major portion of the pressure differential from the pump discharge to the return of the recirculation. In this manner, the pressure loss across the control valve (which is generally either open or closed) is nominal and will not cause undue valve wear. The size of the pressure-reducing orifice is selected so that the flow through the recirculating line will correspond to the minimum flow through the pump recommended by the manufacturer.

Let us reconstruct some additional data on this installation. The recirculating by-pass line will incorporate a control valve which is probably designed to take a 250 to 300 foot drop across it when it is wide open. Thus, the total head developed by these pumps is probably of the order of 6300 feet when running at constant speed.

A 100 per cent performance curve of a typical high pressure boiler feed pump operating at both constant and variable speed is shown on Fig. 1. If we assume that the temperature at full load is 320 F (sp. grav. = 0.908), the rated capacity is 1540 gpm. If 6300 feet represents 119 per cent of the rated head, the latter is about 5300 feet.

If the system-head curve for your installation approxi-

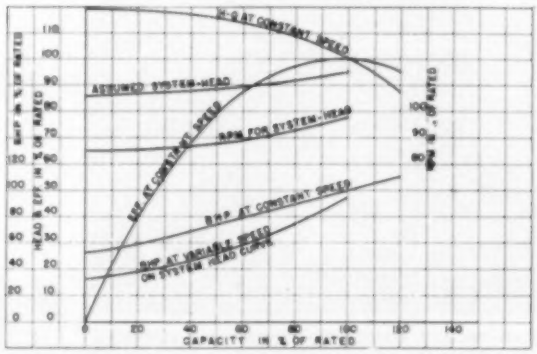
H-Q AT CONSTANT SPEED
ASSUMED SYSTEM-HEAD
RPM FOR SYSTEM-HEAD
BHP AT CONSTANT SPEED
BHP AT VARIABLE SPEED ON SYSTEM HEAD CURVE
HEAD & EFF. IN % OF RATED
BHP IN % OF RATED
CAPACITY IN % OF RATED

Fig. 1—Typical boiler feed pump performance curve, expressed in terms of percentage of its rated design conditions

* Consulting Engineer and Manager of Planning, Harrison Div.

mates that indicated on Fig. 1, the total head which must be developed by the pump on variable speed at light load will be about 86 per cent of its design total head of 5300 feet—or 4560 feet. This will be the pressure differential across the orifice and the control valve. (I am disregarding the friction losses in the recirculation piping.) The flow through orifices or valves varies approximately as the square root of the differential pressure across them. In your particular case, therefore, this flow will be:

$$\text{By-pass flow on variable speed} = 300\sqrt{\frac{4560}{6300}} = 255 \text{ gpm}$$

The by-pass flow is intended to dissipate the heat generated by the pump horsepower losses when operating at extremely reduced flows. The quantity of the required by-pass flow is therefore a function of the pump BHP at shut-off. If 300 gpm was adequate for constant speed operation, the required by-pass flow at variable speed operation can be calculated from the relation:

$$\text{Required by-pass flow at variable speed} = 300 \times \frac{\text{Shutoff BHP at variable speed}}{\text{Shutoff BHP at constant speed}}$$

Applying values from the curves on Fig. 1, we get:

$$\text{Required by-pass flow at variable speed} = 300 \times \frac{32\%}{52\%} = 185 \text{ gpm}$$

The 255 gpm that will flow through the recirculating by-pass line is therefore amply in excess of that required.

QUESTION

Do you know of any "zero speed indicator" which could be applied to boiler feed pumps and which might be tied in with automation, such as would prevent trouble caused by check valve failure and the subsequent running of the pumps backwards? We experienced such an accident recently with considerable damage to the pumps.

The idea would be to use a zero speed indicator and tie it in somehow with an automatic valve, so that back flow through the pump would be prevented when the pump is at rest.

ANSWER

A "zero speed indicator" is a readily available gadget. We have furnished electric speed indicators of at least three different makes with our boiler feed pumps. Any one of these can probably be provided with a contact showing that the speed is zero or even that it has fallen to some 30% or 50% of rated and, therefore, that the pump is coming to rest.

Of course, the problem now is what to do with this impulse. If the discharge gate valve is motorized, the impulse could be applied to energize this valve and close it. But such a valve may take from 20 to 40 seconds to come to a fully closed position. It is possible, therefore, that with the pump motor deenergized and the check valve stuck open, the pump will have come to a full stop in a matter of some 5 seconds under the turbining action of the reverse flow and will have reversed itself before the motorized valve has closed entirely. Still, the protection afforded to the installation by this arrangement is a bit better than nothing.

Actually, I am much in favor of motorized gate valves in the boiler feed pump discharges. If one is installed, I recommend that it be closed before the motor is tripped out. If an automatic arrangement is desired, it is very simple to install a time-delay-relay of a duration just in excess of the motorized valve closure time. Then, when it is desired to bring a pump to rest, the trip switch starts closing the discharge valve and, after it is closed, deenergizes the motor.

Of course, this gives no protection against an accidental motor trip-out. But if pump speed indication is also made to provide an impulse to start closing the gate valve, a definite improvement in protection will be obtained.

Bear in mind that proper relay sequence is necessary for the reverse operation, that is when the pump is started up. Either the motorized valve must be capable of being opened even at reduced speed when the pump is coming up from rest, or the valve must be left closed until the pump comes up to full speed. Remember that if the pump is properly protected by an automatic recirculation by-pass, there is no danger in operating it against a closed gate valve.

Ash Removal Problem Solved

Removal of ashes is an important step in the generation of steam and especially so in an installation as large as that at the Eastlake plant of the Cleveland Electric Illuminating Co. Some 400 tons of ash accumulate daily. Pits must be cleaned frequently and thoroughly, and with a minimum of labor, to ensure continued efficient and economical operation of the boilers. Ashes must be removed every 8 hours, and this is done by flushing with water. There is an accumulation of about 15 tons at each flushing.

Water is pumped directly from Lake Erie, through a $^1/_8$-in. mesh screen, without cleaning or processing of any kind. It therefore contains a large amount of sand and other coarse material which is carried through the flushing system. A secondary, but equally serious problem, is the shock of the water hammer due to pressure built up suddenly when the valve is closed. This closing action has proved costly in lost production time, maintenance time and the frequent replacement of broken valves since the original valve was unable to withstand the water hammer, the pressure of which sometimes reached as high as 900 psi.

Republic Manufacturing Company was called in to develop a new design that would solve these problems and it did with a 3-way, 3-in. rubber faced plug with 300 psi flanges made of a high tensile, semi-steel casting, keyed to a steel stem or shaft. This design has now compiled enough experience to indicate its soundnes.

Economic Improvements of a Combined Cycle Plant Over a Conventional Steam Cycle Plant*

By H. J. PETERSEN†
United Engineers & Constructors Inc.

and

J. O. STEPHENS‡
Westinghouse Electric Corporation

THE power plant designer of today is greatly concerned with the difficult task of reducing the cost of electric energy to the consumer. Over the years his achievements in this area, in the face of rising material, labor and fuel costs, have been outstandingly successful. However, as each new cost-saving concept (such as higher steam temperatures and pressures) is exploited to its fullest, the law of diminishing returns sets in, and he is forced to seek new sources of economical generation. One of these sources, which holds great promise, is the combination gas turbine-steam cycle plant. This paper sets forth the results of a study the authors have made comparing the capital and energy costs of a large size power plant, using gas and coal in a combination gas turbine-steam cycle with a conventional coal-fired plant of the same net output.

Operating Conditions

Fig. 1 shows the heat balance for the conventional cycle. Steam conditions are 2400 psig, 1000/1000 F and all results are referred to 1-in. Hg abs exhaust pressure. The unit has one double-flow high-pressure turbine, one double-flow intermediate-pressure turbine and two double-flow low-pressure turbines with a conventional condenser underneath each low-pressure turbine. There are six stages of feedwater heating, plus one deaerator. All of the heaters, except the deaerator, are in strings of two, and the two lowest pressure heaters in each string are located in the neck of each of the two condensers. Final feedwater temperature is 483.8 F. There are four boiler feed pumps (one as a spare) driven by high-pressure turbines of 8880 hp each, which take steam from the outlet of the high-pressure section of the main turbine and exhaust to the deaerator.

The gross output is 705,500 kw and, with the auxiliaries requiring 27,000 kw, the net output is 678,500 kw. A boiler output of 4,730,000 lb per hr is required and, with a boiler efficiency of 89 per cent, the net plant heat rate is 8962 Btu per kwhr.

Fig. 2 shows the heat balance for the combined cycle. Steam conditions are the same as for the conventional cycle. This cycle uses two strings of four stages of feedwater heating, plus one deaerator. In addition, this cycle has one low-level economizer on each side of the deaerator utilizing exhaust flue gas heat. This results in the same feedwater temperature of 483.8 F as the conventional cycle.

The gross output of the steam cycle is 613,300 kw and 78,700 kw are added from the gas turbine; with auxiliaries requiring 13,500 kw, the net output is 678,500 kw which is the same as for the conventional cycle. A boiler output of 3,900,000 lb per hr is required and the net plant heat rate is 8666 Btu per kwhr. This is a gain over the conventional cycle of 296 Btu per kwhr or 3.3 per cent.

The principal reason for this gain is that the part of the total power output of the plant produced by the gas turbine is a function of the total energy extracted from the gas, and is represented by a drop in temperature from 1450 F at the turbine inlet, exhausting at 825 F in the firebox of the furnace, to 300 F, the temperature of the exit gas at the stack, or 1150 degrees available. In the conventional steam unit this temperature drop is

* This paper presented here in its entirety was presented at the American Power Conference, Chicago, Ill., March 21–23, 1961 under the title "Improvements In Economics of A 678.5 Mw Combined Cycle Plant Over A 678.5 Mw Conventional Steam Cycle Plant."
† Vice President and Power Consultant.
‡ Manager of Engineering—Gas Turbines.

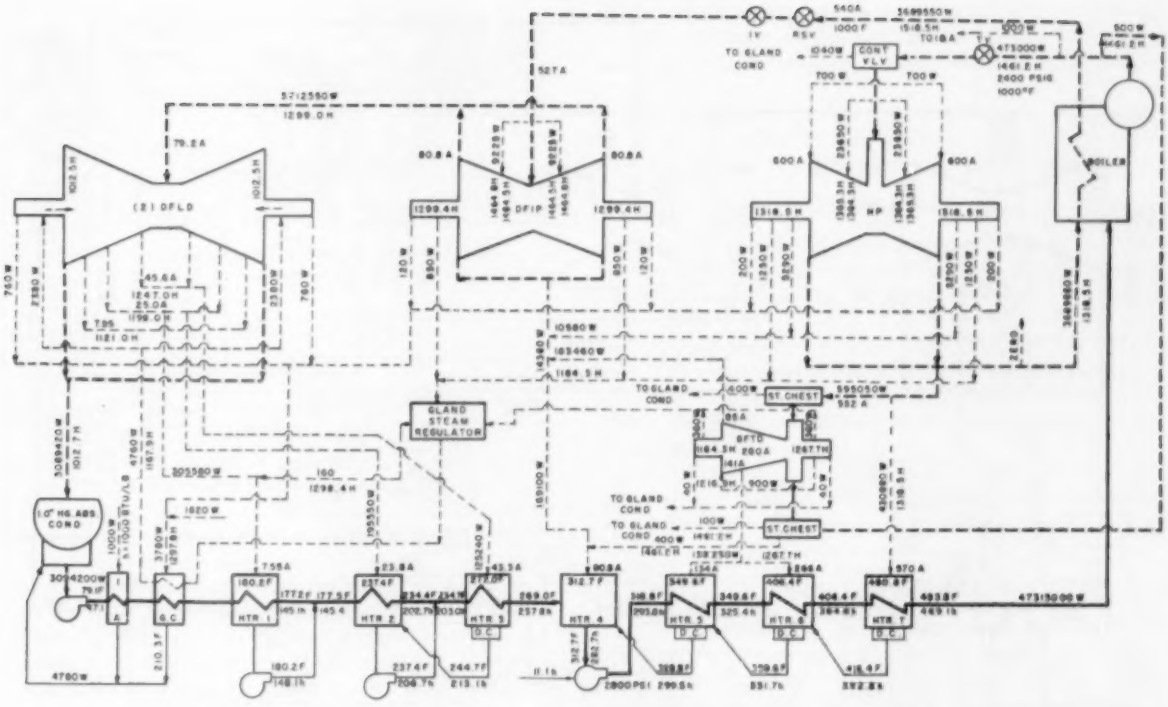

Fig. 1—Heat balance diagram is sketched out for the conventional cycle used as the basis of comparison

from throttle temperature of 1000 F to condensate temperature of 100 F, or 900 deg available.

Basic Data

These basic data are tabulated in Table I.

Forced-Draft Fans

The original concept omitted forced-draft fans since the gas turbine acts in this capacity. However, forced-draft fans may be used to supercharge the turbine and maintain constant gas turbine output at ambient temperatures above 60 F when filter washers are used between the forced-draft fans and the compressor inlets. In order to evaluate the effect on the capital and energy costs if forced-draft fans were to be installed, a supplementary comparison was made to include this equipment.

TABLE I—BASIC DATA

	Combined	Conventional
Steam turbine output, kw	613,300	705,500
Gas turbine output, kw	78,700	0
Total output, kw	692,000	705,500
Auxiliary power, kw	13,500*	27,000
Station net output, kw	678,500	678,500
Net plant heat rate, Btu kwhr	8,666	8,962
Difference, Btu kwhr	−296	
Gain in efficiency, %	3.3	
Steam generated, initial lb per hr	3,900,000	4,730,000
Steam generated, reheat lb per hr	3,134,430	3,689,550

* Without forced-draft fans.

These fans are sized to carry full load on the boiler with the gas turbine out of service. The cold air is routed around the turbine, directly into the coal-fired furnace. The boiler can operate on cold secondary air, but two air preheaters are included to supply hot air for drying the coal.

Due to the required fan power, the net output of the steam portion of the combined-cycle plant will be 5000 kw less. However, because the forced-draft fans supercharge the gas turbines, the increased output of these turbines is approximately 10,000 kw. In this study we have not taken credit for the net extra 5000 kw, but have assumed that the extra fan power required equals the extra output obtained from the gas turbines.

Description of Units

The steam generators for both cycles are of the same type consisting of a single drum with twin pressurized furnaces, each complete with a superheater, reheater and economizer. An auxiliary boiler is provided for plant heating and to start the gas turbine.

The steam turbine for the combined cycle is a cross-compound unit with a 3600-rpm shaft driving a double-flow high-pressure section, a double-flow reheat intermediate-pressure section and a 442,000-kva generator. The 1800-rpm shaft drives a twin unit, double-flow exhaust section and a 291,645-kva generator.

One simple cycle gas turbine unit is provided consisting of two separate shaft gas turbine driven compressors driving one single-shaft gas turbine and one 88,235-kva generator. The gas turbine is described in more detail later.

Current is generated at 20,000 v.

The turbine for the conventional cycle is a cross-compound unit with a 3600-rpm shaft driving a double-flow high-pressure section, a double-flow reheat intermediate-pressure section and a 500,000-kva generator.

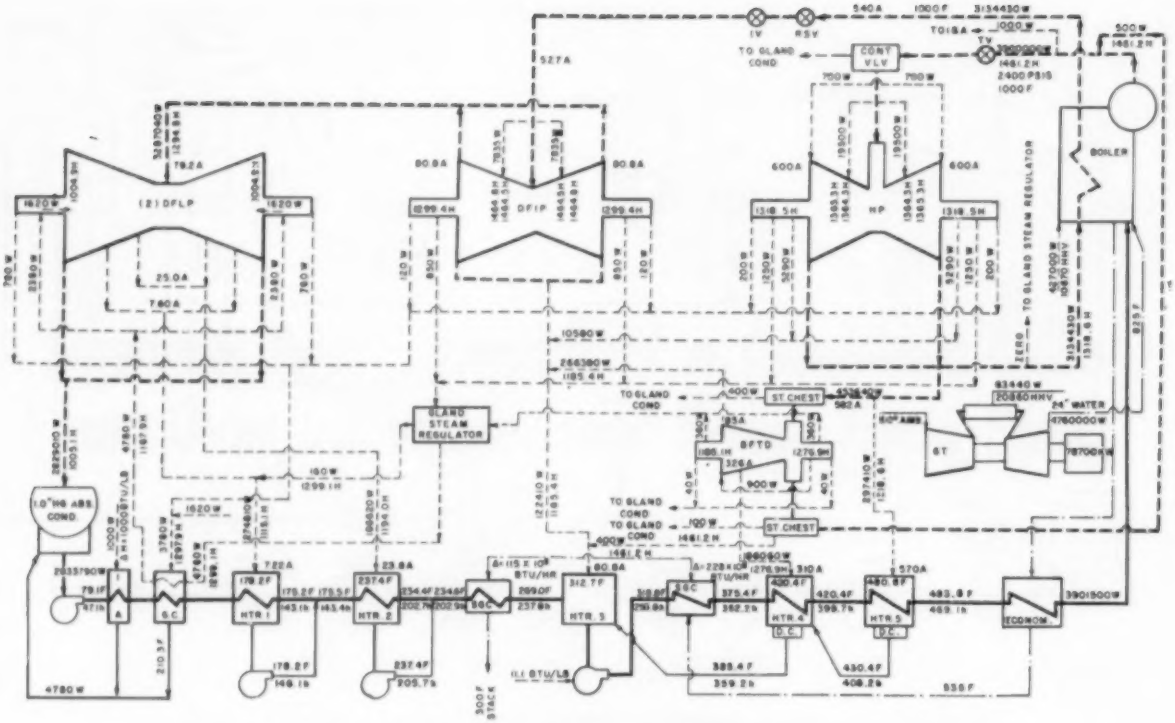

Fig. 2—The heat balance diagram for the combined cycle is depicted here for the same conditions as Fig. 1

The 1800-rpm shaft drives a twin unit, double-flow exhaust section and a 331,765-kva generator.

Current is also generated at 20,000 v.

Power factor for both plants is 0.85.

Station Design

Obviously, since this is a hypothetical plant, certain design assumptions are necessary in order to arrive at a capital cost. Design philosophies vary considerably between different utilities; however, since these assumptions are the same for both types of plant, their effect on the comparison between the two types is minimized.

The plant design is based on weather conditions varying from hot, dry summers to very cold and snowy winters. All equipment, except the fly ash collectors, is located indoors. The main building is constructed of insulated aluminum panel siding. The screen house is built of brick and, where practical, the coal conveying belts run in galleries enclosed by corrugated aluminum siding. The plant offices and main control room are air conditioned. A freight and passenger elevator serves all platforms around the boiler. The main operating floor in the turbine room is common to both the gas turbine unit and the steam turbogenerator.

Condensing water for the main unit is delivered through concrete pipes by vertical pumps located in the screen house at the river's edge. One pump serves each half at the divided waterbox, single-pass condensers.

Demineralizers and chemical feed pumps condition the make-up and boiler feedwater.

A traveling crane with a 100-ton main hook and an auxiliary hook serves the turbine room.

The electrical switchgear, auxiliary transformers, relays, cable room and storage battery are centrally located between the ground and main operating floors in order to provide short cable runs to large motors. The main transformers are placed outdoors adjacent to the turbine room wall to minimize the length of generator leads.

The coal handling equipment is designed to receive and transport both rail and water-borne coal at a rate large enough to do the job on a single-shift basis. Storage areas for a ninety-day supply of uncrushed coal are provided. The boiler house bunkers will hold a forty-eight-hour supply for the boiler operating at full load.

The hydraulic ash handling system will remove ashes from the wet hoppers under the furnaces, also pyrites from the coal pulverizers, and deliver these waste materials to an elevated silo adjacent to a railroad spur. The fly ash will be transported pneumatically for storage in two silos.

A 10,000-bbl tank with earth dike will contain light fuel oil for stand-by use in the gas turbines. Natural gas at 160 psig pressure and 1000 Btu per cu ft, and coal with a heating value of 10,670 Btu per lb (as fired), is assumed as the fuel for the turbine and boiler respectively.

Gas Turbine

The first power generating gas turbine by the co-author's company was installed eight years ago and has operated in excess of 60,000 hr. During this time the total kilowatthour output from this 5000-kw unit has been 100 per cent of nameplate rating. This record of performance and reliability on the first machine, plus similar success on approximately one hundred subsequent

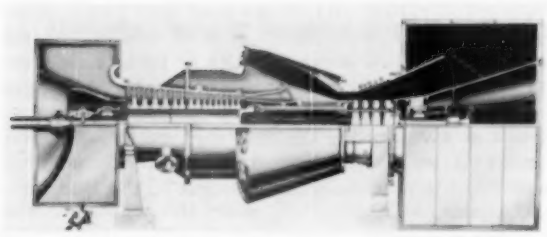

Fig. 3—The modular concept of the 25-mw gas turbine is shown in the cross-section above

machines, has established this prime mover as equal to other types of power plant apparatus in these respects.

The gas turbine used in this study is a 75-mw single generator gas turbine rated at 60 F at elevation 1000 ft. Through a modular concept of combining developed components, a single generator is direct driven by a separate gas turbine, thereby eliminating multiple generators. This modular concept consists of two 25-mw gas turbine power plants, a cross-section of which is shown in Fig. 3, driving air compressors that feed the combustion system for the same size of gas turbine. Since a 25-mw gas turbine power plant normally delivers 75 mw of power, 50 mw of which is required to drive the compressor with the remaining 25-mw output power, the elimination of the air compressor allows the full 75 mw of the gas turbine to be delivered to the generator.

This arrangement also provides some variable exhaust flow operation inasmuch as the compressor sets can be varied in speed from approximately 85–100 per cent speed.

The net plant heat rate of the combined cycle when operating in this manner is illustrated in Fig. 4. From full load at 100 per cent speed with two compressors operating, the speed of both compressors is reduced with load to 85 per cent speed maintaining a constant fuel/air ratio. At this point an increasing part of the air from both compressors is bypassed around the furnace to the economizer. This is done to maintain a constant fuel/air ratio in the furnace to prevent excessive degradation of plant heat rate. When half load is reached, one compressor operating at full speed is sufficient for combustion air requirements. The drop in the heat rate curve is evident.

An added degree of reliability is provided in that the generator shaft may be taken out of service and, with the two compressor shafts operating, exhaust flow to the boilers will be maintained at approximately 100 per cent with a slight reduction in exhaust temperature.

Fig. 5 shows the modular arrangement of these two gas turbines. The two compressor gas turbine plants consist of standard 25-mw gas turbines, driving compressors from 12.5-mw gas turbines. As mentioned before, the gas turbine portion of a plant delivers 75 mw of work, 50 mw of which is absorbed in the compressor end and 25 mw is to output power. Therefore, the gas turbine is capable of driving through a step-up gear a compressor half the size of its own compressor. Since the next smaller frame size turbine is approximately half of the 25-mw plant, driving the full axial compressor from this plant matches the power output of the 25-mw plant. By eliminating the axial flow compressor, the same turbine and combustion system are used inasmuch as the air supply from the two compressor sets match the requirements for the combustion system and gas turbine. In this size range of gas turbine, the speed is 3600 rpm so no gearing is required between the turbine and generator.

This 75-mw plant is arranged so that it can be installed at the site location for the future combined-cycle plant and may be used in prior years as a peaking plant.

Capital Costs

Table II shows the power station capital costs for both cycles. Within the accuracy of estimating procedures for large plants, the total costs may be assumed to be equal.

Items not included in these estimates are: (1) Cost of land, (2) clearing site, (3) roads and railroads off site, (4) switchyard and transmission facilities beyond generator leads, (5) escalation and (6) interest during construction.

These items are essentially equal for both cycles and, since we are dealing with comparisons, their addition would have no significant effect on the results of this study.

Energy Costs

Table III shows the energy costs which are based on a load factor of 80 per cent full load for the unit, and carrying charges of 14 per cent. An operating and maintenance charge of 0.4 mills/kwhr was applied to total output of both cycles. For the combined cycle an annual charge of $30,000 was included for added maintenance labor and material for the gas turbine portion of the plant. A ninety-day fuel supply with inventory cost at 4.5 per cent is provided. The results in this table are based on an assumed typical case wherein the cost of both coal and gas is thirty cents per MMBtu. For this case, the annual operating saving of the combined cycle over the conventional cycle is $558,000.

TABLE II—POWER STATION CAPITAL COST (THOUSANDS)

		Combined	Conventional
311	Structures and improvements	$12,218	$12,243
312	Boiler plant equipment	38,812	42,957
314	Turbine generator equipment	28,239	24,586
315	Accessory electrical equipment	4,423	4,561
316	Miscellaneous power plant equipment	1,010	998
	Total direct cost	$84,702	$85,345
900	General items	7,550	7,550
	Contingency	4,618	4,645
	Total	$96,870	$97,540
	Forced-draft fans	700	*
	Total	$97,570	$97,540

* Included in Account 312

TABLE III—ENERGY COSTS—MILLS PER KWHR

	Combined	Conventional
Fixed charges	2.849	2.869
Operating and maintenance charges	0.506	0.500
Fuel cost		
Gas	0.584	0
Coal	2.010	2.688
Fuel inventory	0.028	0.038
Total cost, mills per kwhr	5.977	6.095

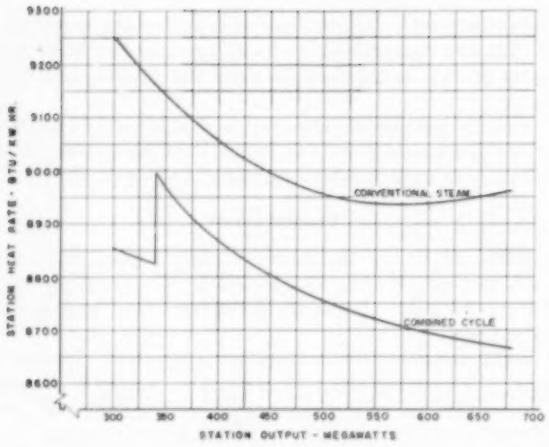

Fig. 4—Comparison curves of the plant heat rates for both conventional and combined cycles

Comparison of Operating Costs

Fig. 6 shows the operating cost break-even lines between the two cycles for varying coal and gas fuel prices, using the capital costs indicated in Table II. Any combination of coal and gas prices resulting in a point above these lines indicates a saving in favor of the combined cycle. Conversely, any point below these lines results in a loss when using the combined cycle.

Line "A" is plotted using an 80 per cent load factor for the unit. Line "B" is plotted using a 40 per cent load factor for the unit. Both of these lines are less the forced-draft fans. Line "C" takes into account the cost of these fans.

Using a typical example, assume coal costs thirty cents per MMBtu. At 80 per cent load factor, which would be conservative for an efficient unit of this size, any gas cost at 36.0¢ per MMBtu or lower results in a saving by using the combined cycle. At 40 per cent load factor, any gas cost of 37.0¢ per MMBtu or lower results in saving using the combined cycle. This indicates that within commercial load factors, the break-even point is practically independent of the load factor of the unit.

If the cost of the forced-draft fans is included (Line "C"), the break-even point, at 80 per cent load factor, lowers to a gas cost of 35.0¢ per MMBtu.

Conclusion

As noted, the total costs of these two plants are essentially equal. The combined cycle shows a 3.3 per cent gain in efficiency over the conventional plant, with a net plant heat rate of 8666 Btu per kwhr. In order to obtain these low heat rates with a conventional plant, it would be necessary to resort either to 1100 F temperature with 2400 lb pressure, or go to 3500 lb pressure in the 1000/1050 F range. The operating disadvantages and higher costs of either of these two alternatives over the combined cycle are obvious.

The example chosen to illustrate energy costs, i.e., thirty cents per MMBtu for coal and thirty cents per MMBtu for gas, is fairly typical of fuel prices in the midwestern area. Under these conditions the cost of energy is less than 6 mills per kwhr. Also, although the plant capital costs are the same, there is an operating saving of $558,000 per year in favor of the combined cycle.

For these reasons we believe that the combined gas turbine, coal-fired steam-cycle plant is economically attractive to those utilities or power pools requiring large size units where the combination of fuel prices for coal and gas fall in the saving area shown on Fig. 6.

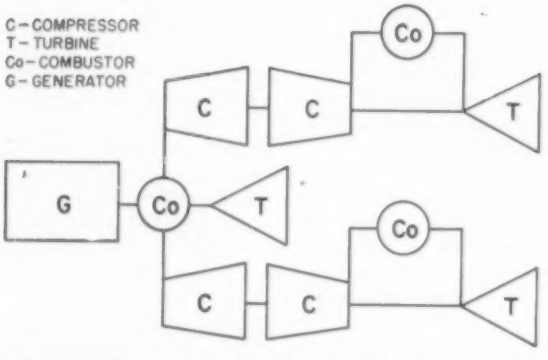

Fig. 5—Schematic view above shows how the modular gas turbine idea is worked

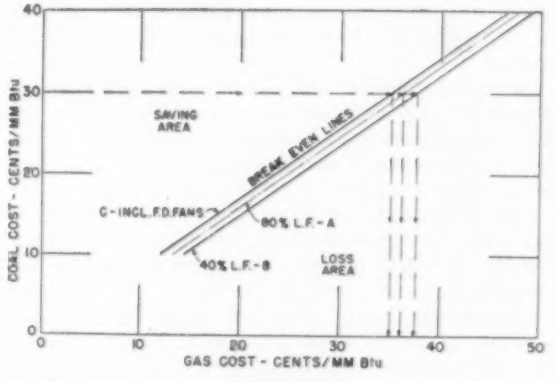

Fig. 6—Using the capital costs of Table II the operating cost break-even lines are sketched for varying fuel costs

Abstracts from the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Power Generation and Power Plant

High Efficiency Boiler Plant at a Devon Pottery Works. Anon. *Steam Engr.* 1960, **30** (Nov.), 47–52.

Candy and Co. Ltd. have installed a Centrax boiler for providing 2500 lb/hr of steam at 100 psi which is provided with a Riley (IC) Type HL (high-low-off) burner which consists of a small burner for lighting off and low load and a large recirculating burner for full load. The oil (950 sec) is preheated to 220 F before being admitted to the burners which operate at a pressure of 300 psi. The oil metering and control installation is also described. The thermal efficiency of the boiler is up to 85 per cent.

15 Mw Gas Turbine Alternator for Peak Power. Anon. *Elect. Times* 1960, **138** (Nov. 17), 255.

A 15 Mw gas turbine set is to be installed at Hams Hall for operation in the autumn of 1962. Fuel consumption is estimated to be 0.752 lb/kwhr.

America's H.T.G.C.R. Anon. *Nucl. Energy* 1960, (Nov.), 539–41.

The reactor under construction at Peach Bottom and to be completed in 1963 will have a thermal output of 115 Mw and an electrical output of 40 Mw and produce 336 klb/hr of steam at 1450 psi and 1000 F. The fuel is enriched uranium and thorium carbide mixed homogeneously with graphite in graphite sleeves. Coolant is helium at 20 at. pressure with an inlet temperature of 660 F and an outlet temperature of 1380 F. The overall net thermal efficiency is 34.8 per cent.

Materials and Manufacturing Processes

Cracking in Welded Joints of Austenitic Steel in C.E.G.B. Power Stations. F. E. Asbury, B. Mitchell and L. H. Toft. *Brit. Weld. J.* 1960, **7** (Nov.), 667–78.

Examination of cracks in the heat-affected zones of welds of 18 per cent Cr–12 per cent Nb steel showed these to be in a hardened condition due to straining and hardening by precipitation of niobium carbide leading to a reduction in ductility, particularly at low rates of straining.

The Heat-Affected Zone of Arc-Welded Iron. E. F. Nippes, W. F. Savage and W. A. Owczarski. *Weld. J.* 1960, **39** (Nov.), 465s–72s.

Based on the results of an investigation into the changes of microstructure and physical properties it is recommended to avoid fusion of the base metal because of the resulting embrittlement. Braze welding or arc welding with electrodes with melting points around 2000 F is suggested.

Particularities of Austenitic Transformation and Formulation of "Cold" Cracks in Fusion Welding. N. N. Rykaline and M. K. Chorchorov. *Soudage* 1960, **14** (Sept./Oct.), 335–47 (in French).

The structural changes in base and weld metal have been studied as a function of heating and cooling rates. Welding processes and conditions excluding any possible formation of "cold" cracks are indicated.

Creep in Steel. Technological Aspects of the Subject. J. D. Murray. *Iron and Coal Tr. Rev.* 1960, **181** (Nov. 4), 1007–13.

A review of recent investigations into the effect of various alloys on the creep resistance of steel.

Heat-resistance of Austenite Alloys Under Non-Stationary Test Conditions. L. B. Getsov and M. G. Taubina. *Teploenergetika* 1960, **7** (Sept.) 40–44 (in Russian).

The paper discusses the fatigue strength of two types of austenitic steel and two nickel-base alloys subjected to cyclic changes of temperature and stress up to 1550 F and 59500 psi. *C.E.G.B. abstract.*

Designing Very High-Pressure Steam Piping for Strength. A. V. Ratner and M. Ya Aristov. *Teploenergetika* 1960, **7** (Sept.) 44–9 (In Russian).

A description is given of an experimental determination of the compensating forces and bending moments in steam piping for steam up to 980 F and 3380 psig. Suggestions are made for a more accurate method of designing steam pipes for strength.

C.E.G.B. abstract

High-Temperature Steel Welding Problems. Pt. II. E. Kauhausen, P. Kaesmacher and S. Sadowski. *Werkst und Betr.* 1960, **93** (Oct.), 238–43 (in English).

The second part deals with: (1) Fields of application and properties of austenitic steels; (2) Additional all-austenitic welding materials; (3) Formation and cause of cracks; (4) Welding; (5) Welded joints between ferritic and austenitic steels.

Welding of Nickel-Chromium-Iron Alloy for Nuclear Power Stations. C. E. Witherell. *Weld. J.* 1960, **39** (Nov.), 473s–8s.

For the welding of 15 per cent Cr–7 per cent Fe nickel alloy a new nickel-chromium-iron alloy electrode and inert-gas filler wire have been developed which produce crack-free and porosity-free welds in all positions. The electrode can be used also for welding the alloy to carbon and stainless steel.

Shop Fabrication for Hinkley Point. Anon. *Weld. Met. Fabr.* 1960, **28** (Nov.), 424–33.

The fabrication and welding of the pressure vessels, heat exchangers and diagrid are described including: (1) Inspection of plate material; (2) Pressing of plates; (3) Welding; (4) Fabrication of steam raising units; (5) Inspection; (6) Stress relief; (7) Fabrication of diagrid.

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Shop Fabrication at Hinkley Point. Anon. *Weld. Met. Fabr.* 1960, **28** (Nov.), 434–47.

A detailed description of the assembly and welding of prefabricated parts of the pressure vessels and heat exchangers, inspection methods used and final installation is presented.

Instruments and Controls

Automation—Boiler Operation. G. W. Kessler. *Mech. Engng.* 1960, **82** (Nov.) 68–71.

Although it is known what is required of complete automatic control of boilers it is considered that computers presently available are not yet reliable enough and also very expensive to install and maintain. Computer programming, methods of automation, boiler design for automation and simulation of boiler automation are discussed.

Automation—Economic Justification. W. T. Hess. *Mech. Engng.* 1960, **82** (Nov.), 74–5.

Complete automation would increase safety and reliability, full and maintenance economy.

Flame Monitoring—Important Key to Unit Automation. Anon. *Power* 1960, **104** (Oct.), 151–4.

One of the most important items to be monitored in a power plant for reasons of safety of operation is flame failure. Various types of flame sensors are described. Equally important are flue gas and combustibles analysers to obtain early warning of the formation of an explosive mixture in the furnace. A combination of flame failure and flue gas analyser appears necessary for automatic control.

Pressure and Velocity Measurements on a Double-Venturi and a Standard-Venturi Orifice. W. Kühnel. *Energie* 1960, **12** (Oct.), 446–9 (in German).

The results of pressure and velocity measurements on a double and a standard venturi orifice and the influence of a length of pipe upstream are reproduced in curves. Simultaneously, the point of maximum negative pressure was located in both orifices.

Measurement of Flow Coefficients and Pressure Drop in Double-Venturi Orifices. R. Speer. *Energie* 1960, **12** (Oct.), 449–52 (in German).

Flow coefficients and pressure drop were measured in 5 double venturi orifices with opening ratios of largest to smallest diameter of 0.1, 0.255, 0.35, 0.475 and 0.6. The flow coefficients of the new orifices are 10–15 per cent lower than those of the original double venturi and it is thus

possible to use larger opening ratios and lower pressure drops. After a small initial decrease of the coefficient this remains constant over a large range of Re numbers.

The Solid Image Microscope. R. L. Gregory. *Research* 1960, **13** (Nov.), 422–7.

The general principles and design of the solid image microscope are described and possible applications discussed.

Nuclear Energy

Dynamic Programming and Nuclear Reactor System Design. N. Kallay. *Nucl. Sci. Engng.* 1960, **8** (Oct.), 315–25.

Applications of dynamic programming techniques to nuclear reactor optimization problems are considered.

Some Aspects of Fluid Fuel Reactor Development. A. M. Weinberg. *Nucl. Sci. Engng.* 1960, **8** (Oct.), 346–60.

A detailed review of the merits and disadvantages of fluid fueled reactors and the need for further experiments to assess their value as breeders.

Power Reactors—The Next Ten Years. F. K. Pittman and U. M. Staebler. *Mech. Engng.* 1960, **82** (Nov.), 76–9.

The development of nuclear reactors for power stations as seen by the U. S. Atomic Energy Commission is discussed. The various types of reactors and their probable applicability are described.

Structural Materials for Nuclear Reactors. J. L. Bernard. *Tech. Mod.* 1960, **52** (Oct.), 467–75 (in French).

The structural materials considered are those employed for the core, pipelines, heat exchangers, supports and struts and fuel element cans. The intrinsic quality required for each application (nuclear, mechanical), and the extrinsic quality (corrosion resistance) and effects of irradiation are discussed and French can design, welding of beryllium and zirconium and the production of fuel element clusters described.

Design and Testing of Large Gas Ducts. A. T. Bowden and J. C. Drumm. *Proc. Inst. Mech. Engrs.* 1960, **174**, No. 3, 119–57.

The problems encountered in designing and testing large gas ducts for nuclear reactors are outlined. The most economic way of meeting the need for high flexibility and low flow pressure loss is discussed and the solution, a combination of tied expansion bellows and cascaded corners, described.

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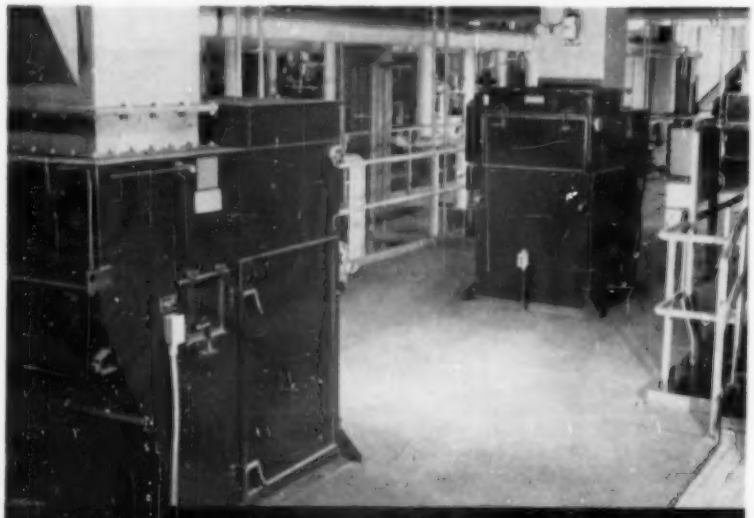

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Fuel Element Shapes. Anon. *Elect. Times* 1960, **138** (Nov. 17), 769–70.

A summary is given of a paper by H. H. Gott, J. Brown and J. P. Bond presented to a symposium organized by the Inst. of Mech. Engineers in which the influence of heat transfer on the performance of gas-cooled power reactors was reviewed. Existing designs of fuel element cans for optimum transfer of heat from the core to the gaseous coolant were described and new designs outlined.

CANDU Fueling Costs—Breaking the 1-Million Kwhr Barrier. A. J. Mooradian and J. A. L. Robertson. *Nucleonics* 1960, **18** (Oct.), 60–6.

The design developments of the fuel elements for the NPD and CANDU reactors are described and the efforts made to reduce fabrication and operating costs are presented.

On-Power Refueling. J. S. Foster, W. M. Brown and H. E. Tilbe. *Nucleonics* 1960, **18** (Oct.), 66–8.

The refueling scheme and machines developed for the NPD and CANDU reactors are described.

Grinding, Screening and Filtering

A Study of the Size Reduction Mechanism of Swing Hammer Mills. T. G. Callcott. *J. Inst. Fuel* 1960, **33** (Nov.), 529–39.

From the evidence provided by high speed cinema photographs and other tests it is concluded that the hammers break the coal in a mild way and that near the gap between hammer tip and breaker bar the size reduction mechanism is a form of localized closed-circuit grinding.

Ni-Hard Grinding Balls Far Outlive Steel. R. H. T. Dixon. *Engineering* 1960, **190** (Nov. 4), 589–9.

Comparative tests of steel balls and those made of Ni-Hard (white cast iron with 4 per cent Ni and 2 per cent Cr, tempered for 4 h at 450 C and 4 h at 275 C) showed the latter to have a vastly superior life. It is claimed that Ni-Hard balls last more than 14 times longer than steel balls.

Analysis and Testing, Research

Code Testing of Large Boilers—Input—Output or Heat-Loss Method? J. A. Bostic and W. F. Long. *Combustion* 1960, **33** (Oct.), 34–7.

The two methods are compared and a new test code proposed. The new equations for calculating the efficiency by either method according to the new code are given. It is concluded that ash pit and radiation and convection losses should be more closely studied to arrive at more accurate figures.

Comparative Dew Point Measurements. H. Rögener. *Mitt. V.G.B.* No. 68, 1960 (Oct.), 343–7 (in German).

The measurements were carried out with 5 different instruments (2 of BCURA design) in the flue gas duct of an oil fired boiler. Maximum difference of dew point temperatures was 45 F. None of the instruments is sufficiently accurate for present-day requirements and advice for their improvement is given. Improvements in measuring technique are also discussed.

Fractional Thermogravimetric Analysis. P. L. Waters. *Anal. Chem.* 1960, **32** (June), 852–8.

This method gives a continuous record of the tar and liquor, CO_2 and H_2S, heavier gaseous hydrocarbons and noncondensable gases evolved during carbonization. In a modified form the carbon and hydrogen evolving in volatile form can be determined and it is thus possible to calculate the average density of the gases evolved during decomposition.

Application of the Thermogravimetric Balance to Studies of the Pyrolysis of Solid Materials. P. L. Waters. *C.S.I.R.O. Coal Res.* Ref. T.C. 34, 1960 (July), 19 pp.

The method itself and its application to the determination of the rate of evolution and chemical composition of tar, liquor and gases evolved from coal on pyrolysis are described. The application to materials other than coal is discussed.

Steam Sampling in Russia. J. Jackson. *Engineering* 1960, **190** (Nov. 4), 627.

Russian methods are described and compared with American tests. The same conclusions are reached in both countries with regard to the best sampling point, i.e., where the steam leaves the drum.

Non-Destructive Testing in Power Plant Inspection. P. W. Sherwood. *Combustion* 1960, **33** (Oct.), 44–8.

It is shown that many of these methods can be successfully used in inspection work and would permit finding faults not detectable by previous methods. The practical application of these methods is outlined.

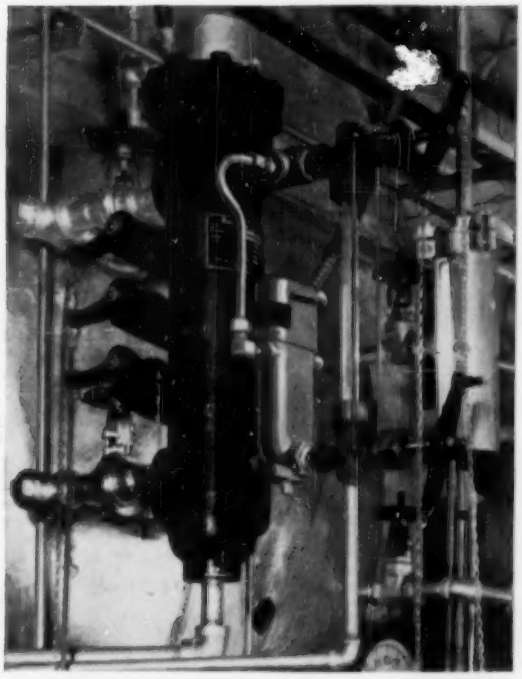

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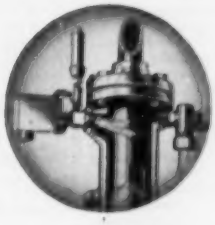
Illustration above shows Levalarm EA-15R on a water column. It can serve as fuel cut-out, or cut-out and alarm. Under the cap on top of the column are terminals of electrodes that extend into the column. They form a Levalarm capable of handling a combination of duties such as listed above.

Other members of the valuable "Levalarm Family" are shown at right. Ask for more complete information on these versatile devices that insure positive, economical warnings and control.



EA-7,
float-actuated switch;
low and high alarm.

EA-100P,
float and electrodes;
single or dual fuel cut-out.

EA-101,
electrode; alarms, fuel
cut-out or pump control.

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5902 Carnegie Avenue • Cleveland 3, Ohio

Reliance® BOILER SAFETY DEVICES

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REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N.Y.C.

1 The Diesel Engine

By L. V. Armstrong and J. B. Hartman

$8.75, 360 pages

This text is subdivided into chapters as is common to most books, but basically it is different in its presentation in that each chapter is edited by an authority in subject matter.

For the edification of the reader, at strategic points, a "base design problem" is injected, pointing up the practical value of the theory involved.

The subdivisions are headed: general, combustion, dynamics, statics, parasitics, and economics. The appendix contains the problems referred to in the subdivisions.

Illustrations, graphs and photographs are used extensively.

This book should be welcomed by student, operator and designer, as it is broad enough to overlap all phases.

2 American Petroleum Refining

By H. S. Bell

$12.50, 538 pages

This book shows the know-how of modern refinery processes and equipment. It includes information on chemical and physical properties of hydrocarbons, crude oil and oil products and the relation of auxiliary service to the main plant.

Flow charts and operating data are complete.

The book is written to give broad coverage for technological information on the refining branch of the industry.

The subjects covered are: history on the growth of the industry, crude oils and their properties, distillation, heat transfer, fractionation, pipe heaters and condensers, cracking—thermal and catalytic, dewaxing and solvent extraction, filtration, blending and compounding, storage, evaporation and service requirements.

3 Nuclear Fusion

Edited by Dr. William P. Allis

$12.50, 488 pages

A carefully worked out presentation of world wide information on "nuclear fusion" from all the papers presented at the Second Geneva Conference.

The topics covered are: controlled thermo nuclear reaction in the U.S.A., the United Kingdom and the U.S.S.R., plasma diagnostics, equilibrium, stability and dynamics, interaction with electro-magnetic waves, pyrotrons, ring discharge, injection machines, stellators, dynamic and sustained pinches.

There is liberal use of graphs, photographs and diagrams with detailed mathematical analysis.

NOTE.—The information contained in this book is all in the field of nuclear physics and is far beyond the scope of the average engineer.

4 A Director of World Activities and Bibliography of Significant Literature on Applied Solar Energy Research

Edited by Joan Smith Jensen

275 pages, no price furnished

Applied Solar Energy Research is intended to supply a central catalog of world literature on applied solar energy and of laboratories and individuals at present active in this rapidly expanding area of research.

It is not exhaustive, as items of ephemeral interest have been omitted, but all genuinely important papers have been included.

A partial list of the subject matter listed is: solar energy—the fuel situation, solar radiation, the use of solar radiation as heat, the use of solar radiation as light.

5 Flames—Their Structure, Radiation and Temperature

By A. G. Gordon and H. G. Wolfhard

$14.00, 383 pages

The aim is to give advanced discussion of a part of the field concerned with stationary flame with emphasis on the physical process occurring in the flame, rather than the chemical viewpoint.

The subjects covered are: premixed flame, flow pattern and shapes, measurements of flame, velocity, mechanics of flame propagation, diffused and unstable flames, solid carbon in flames, radiation processes, flame temperature measurements, ionization and combustion processes.

This is probably as complete a treatise devoted to this field as could be obtained and is without doubt outstanding.

6 Steam Power Plants

By Chas. Donald Swift

$11.50, 491 pages

This book is divided into 20 chapters ranging from initial design concept to plant acceptance tests.

Subjects covered are design and purchase, combustion plant personnel, safety, operation and maintenance, water treatment, cooling towers, condensers, turbo generators, electrical systems. Instruments and automatic control are also covered.

This book was written by a member of a world-wide engineering and consulting service and his work reflects wide personal experiences.

It would be a handy volume for book case of the smaller consulting services in avoiding many of the pitfalls encountered in the preliminary, construction, training, operating and testing periods.

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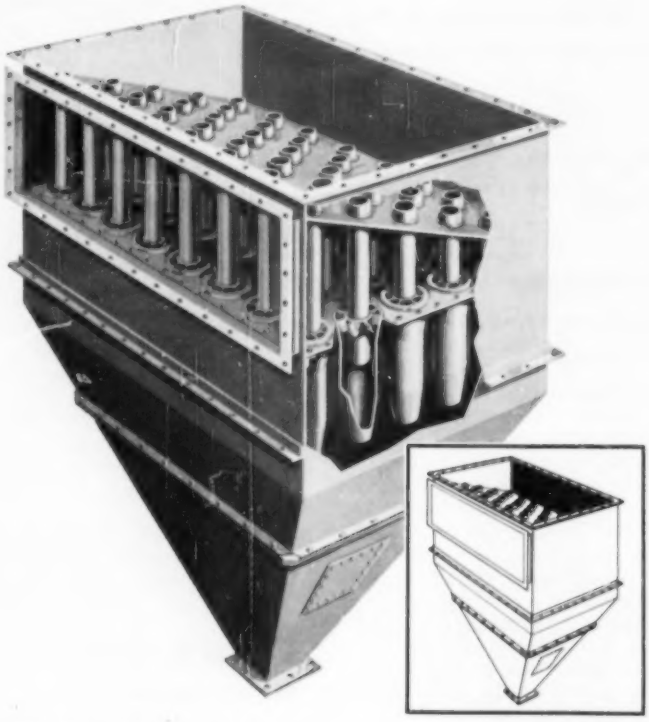

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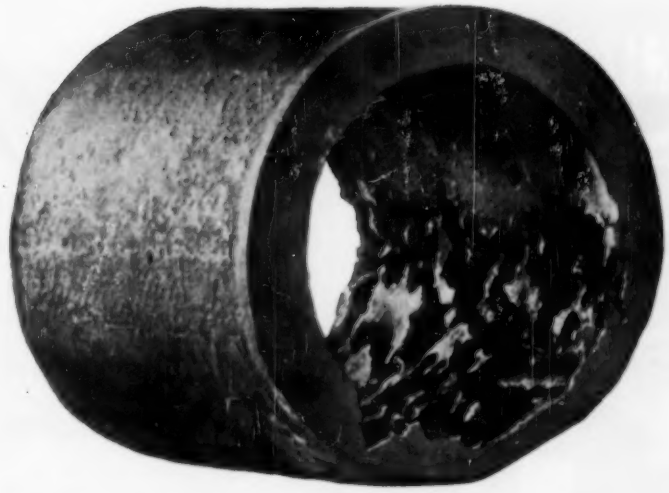

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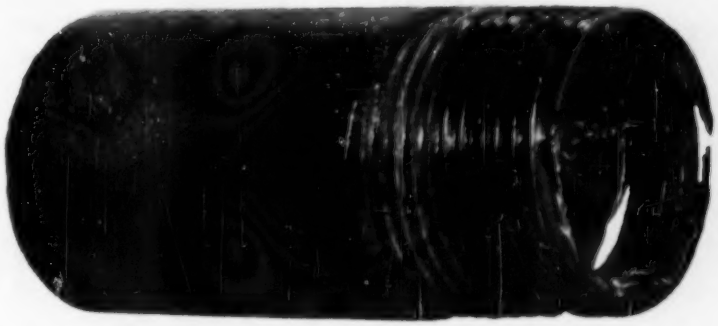

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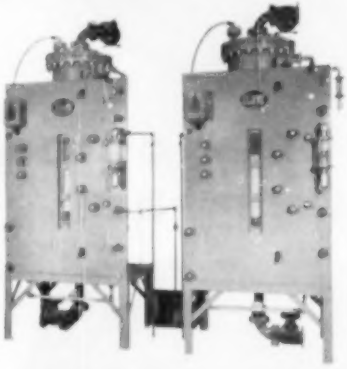

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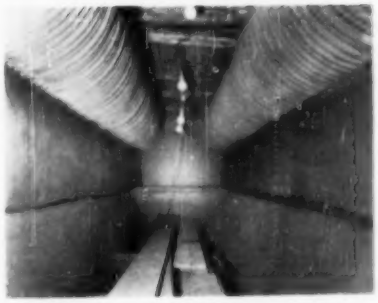

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can help you be sure!

Two FLĀMON Detectors installed for independent monitoring of main burner flame and pilot flame of a gas-fired boiler.

Properly installed, the FLĀMON Detector *responds only to the flame it surveys.* Glowing refractories—or flames from adjacent burners—do not produce false signals. Positive monitoring of each burner is assured. Absence or failure of flame is sensed and accurately signaled—and transmitted to control auxiliaries—without use of external relays or amplifiers.

Key to automation . . . the FLĀMON Detector provides the key to reliable automatic light-off and shutdown.

Provides wide temperature range . . . the FLĀMON Detector can be used in ambient temperatures from −20 to 150°F. Flame-sensing element withstands temperatures up to 500°F.

Allows easy inspection . . . quick-disconnect, keyhole mounting simplifies checking of lens condition and detector alignment.

Simple, solid-state circuitry . . . the FLĀMON Detector unit contains only 10 components.

Weatherproof construction . . . design of Bailey unit makes it suitable for outdoor installation.

Your local Bailey Engineer can give you a demonstration of the FLĀMON Detector. Call him, or write Cleveland.

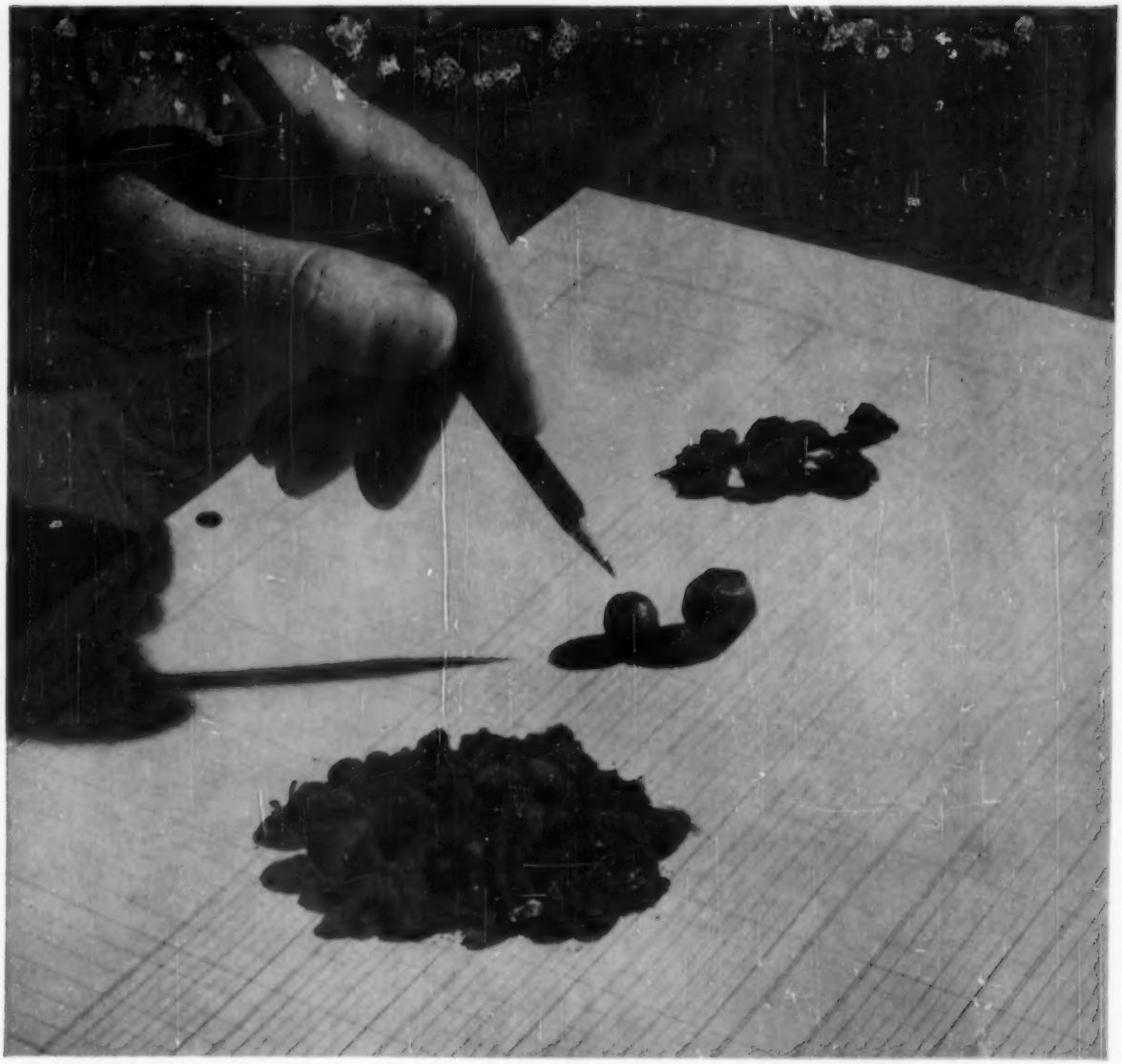
A 162-1

Instruments and controls for power and process

BAILEY METER COMPANY

1025 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal



Specimens of copper powders, balls and balled sheets which can be removed from high-pressure boilers by the M-71 treatment.

M-71 REMOVES THESE COPPER TROUBLEMAKERS FROM BOILERS, FAST!

The M-71 single-stage, patented treatment* for high-pressure boilers removes copper deposits and other scales in record time. With this exclusive Dow Industrial Service treatment, copper does *not replate* on clean boiler surfaces during treatment, and small quantities of M-71 in future cleaning will help *keep* boilers copper-free. To date, the M-71 treatment has cleaned more than 300 boilers.

Copper deposits, common in many high-pressure boilers, reduce heat transfer efficiency and cause localized corrosion, overheating and subsequent ruptures. Copper particles slough off, reducing circulation.

Dow Industrial Service developed the M-71 treatment to remove trouble-making copper and other deposits at the same time. In cases of excessive metallic copper deposits, a preliminary treatment may be desirable.

D.I.S. cleans all kinds of equipment . . . boilers, process equipment, pipelines, water wells, to name a few . . . for every kind of industry. With many methods to choose from, D.I.S. engineers first analyze each job to pick the technique best suited to the specific problem.

D.I.S. also offers complete consulting laboratory service for water treatment and waste processing, backed by the technical resources of The Dow Chemical Company. For fast "total" cleaning of any industrial equipment, anywhere in the U.S.—and for literature on copper removal by the M-71 treatment—write or call DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, Ohio.

*Patent No. 2959555

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